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An Experimental Study of Apparent Movement

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INTRODUCTION

Since the publication of Professor M. Wertheimer's work on perception of visual apparent movement in 1912 much interest has been shown in this country on the problem. However, most investigators used very small stimulus objects in a single observation or at most a few repetitions of single observations. Professor Walter B. Pillsbury suggested that it would be interesting to investigate the same problem by a continuous observation of repeated expositions of the same but much larger stimulus objects than those used by other investigators. Under his guidance and tireless assistance this work was undertaken in the University of Michigan. The author wishes to express her sincere appreciation to him. She also wishes to thank Professor Adelbert Ford for his assistance generously rendered in photographing the material. To the students who served as subjects her hearty thanks are also extended.

HISTORICAL REVIEW

Within the last quarter of a century there have appeared a great number of works on the problem of apparent movement. A review of them discloses great variety in methods, results, and theories, and yet they are treating the same problem and trying to explain the same facts. As it seems impossible to review each of them justly, we shall try to present the main facts of the whole subject, by topics in the developmental order.

Methods and Apparatus:

In the early period the investigations were done with very simple instruments. Stumpf's stroboscopic disk (**45**), for instance, was nothing more than a disk with pictures of successive phases of an object drawn on one side and viewed through radial slits in a mirror while rotating. Or a series of pictures was stationary in the back of the disk with alternate open and close sectors, which, when revolving, gave successive instantaneous views of a moving object. Daedaleum (**30**) and Phantascope (**41**) were all made on the same principle and primarily made to produce the illusory movements.

Schumann was the first to construct a special instrument for experiments of this nature, namely, the Schumann tachistoscope, which was widely used by later workers with more or less modifications. Wertheimer (**55**) used it with some change in the way of presenting stimulus objects. His stimulus object, a line, was carved on the slit which slid into a wooden frame, which in turn was attached to the disk. This disk rotated as the tachistoscope wheel rotated. In front of the object there was set a telescope through which the subjects observed. Close behind the disk there was a prism which reflected the light upon the visual field from the back so that the stimulus object was bright on the dark background. As the disk rotated the stimulus objects were exposed one after the other. The length of the exposure time was varied by the length of the slit and also by the period of

revolution of the wheel. The length of pause was varied by varying the time of revolution and the distance between the two slits which carried the lines. The stimulus line was about 6 cm. by 1 cm. in size and the distance between the subject and the prism was about 80 cm.

About the same time Dodge (11) constructed a transparent mirror apparatus, which depended on the principle of momentary illumination but it corrected the chief defect in the previous apparatus of the same type by providing a suitable pre- and post-exposure field. This provision was developed from the general principle that a glass plate is transparent when the illuminated object lies behind it, while the same plate functioned as a mirror when the illuminated object lies in front. This instrument is a kind of dark box. The objects are inserted through slits in the sides of the box and they are illuminated by the light which is allowed to come through the windows of the box and is reflected by the silver mirrors.

Dimmick (8) and DeSilva (5) added the third stimulus field to the Dodge tachistoscope by insertion of a second transparent mirror. This arrangement made it possible to start with any pre-exposure field with a fixation point. The total visual field was 7 cm. by 7 cm., the stimulus object 1 cm. by 1 mm.

Higginson (25) made several modifications and improved the adjustability of the light intensity and the fixation point which was thrown on the visual field without addition of the third visual field. A device was made to reduce flicker. The rate of rotation and accordingly the temporal interval was widely and accurately varied by a reduction cone and a motor.

DeSilva (7) added another modification to the Dodge tachistoscope to enable us to compare apparent movement with real movement by having four exposure fields.

The most recent apparatus used for the same purpose is Michotte's tachistoscope modified by Godefroy which was used by Waals and Roelofs (52). It consists of two large disks, A and B, which carry exposure openings not exceeding 45°. B is fastened on the axis upon whose opposite end is fastened a pointer W. A can be rotated on the same axis by unscrewing

the screw. On the outside of A a scale is marked from 0° to 360°, so that W will indicate how much B rotated on the scale. Thus it is possible to show the exposure time of the first object, the length of the interval, and the exposure time of the second object in degrees. These can be easily calculated in seconds. Between A and B there are set two prisms which can be rotated independently in either direction. Between each prism and each disk there is a smoked glass plate. On each side of the whole apparatus there is a light source, in front of which a positive lens is placed to collect the beams of light and to throw them on the stimulus object which is placed between the lens and the disk. Each prism gets its beams of light from its respective side through the openings in A and B. After passing the prisms the light beams go through a Zeiss Tessar-anastigmatic lens and fall on the screen with a clear picture of the object. By a slight movement of the prism and the construction of the object you can produce the picture in any relative position; intensity of light can be altered by the smoked glass; color of the object can be changed by means of the color filter which is placed in front of the object. A three-phase motor is used for the regulation of the speed of rotation.

Thus we see a gradual improvement in apparatus. In the earlier apparatus there is only one exposure field, while in the later ones there is the pre- and post-exposure field with a fixation point which does not interfere with the exposure of the object. Besides, more accurate measurement of time is possible. Durations of the exposure times of the first and second objects should be freely varied and the length of pause also should be changed into negative as well as positive values. The Michotte tachistoscope achieved these purposes.

Conditions responsible for the various phenomena are found to be manifold. They are briefly as follows: the exposure time of the stimulus object, the pause between successive exposures, the distance between stimulus objects, color, size, intensity and pattern of the stimulus object, the background, the point of fixation and of attention, the subjective attitude and effect of repetition. The purpose of the experiment is to find the influence

of each of these conditions upon the movement phenomena. Accordingly a good method of experiment must prevent the interference of other factors than the one to be studied. The earlier authors studied some of these factors in certain ways within the capacity of the instrument, and paved the way for the later workers with better apparatus and better controlled methods.

Probably because of the kind of apparatus they had, the earlier workers seemed to attach more importance to the pause with rather short exposure time and tried various lengths of positive pause. Then a discovery was made that the zero pause also could produce the movement phenomena when a certain exposure time was used. Longer exposure times and different lengths of exposure time for the first and the second object were tried as well as negative pauses, which brought out a new situation. By negative time of pause is meant that the two stimuli overlap for a part of the exposure time, or that the second fell entirely within the time of the first. Lengths thus far tried by various people fall within 1000 σ for exposure time and for the pause between —888 σ and +1000 σ including zero.

The size of the stimulus object was naturally small, since the exposure fields of the stroboscope and tachistoscope were not very large. Within that small limit the width or length of the stimulus line, as well as the distance between the two lines were varied to determine the respective influences. The influence of the color of the object and the background was tested in varied combinations: *e.g.*, for the lighted line the black background was used; for the black line the lighted background; for the colored line the lighted, black, or differently colored background. Intensity of the light stimulus was varied from weak to strong and the image was at times focused and at times unfocused. The pattern of the stimulus object was varied from most simple to the complex ones including two dots, two parallel lines, crossed lines, angle forms of varied degrees, geometrical figures, wind-mill type figures and real pictures of a leaping boy, etc. Most experiments had a fixation point somewhere within the exposure field and attention was directed to the same point or elsewhere. With a particular instruction a certain subjective attitude was created and by

repeated observation the influence of predisposition was tested. In a few cases the real objective movement was given for comparison with the apparent movement.

Results:

Movement phenomena are the products of such numerous factors that they can not be so simple nor so definite as other perceptions. Even if we could control all but one factor, a slight difference within that factor will alter that phenomenon to a certain extent; besides individual differences, differences in the instrument, and different experimenters, all of which are responsible for some changes. We ought to expect more or less difference in the fact stated in the same terms because no two experiences will be exactly alike. It will not be fair to treat on the same level the results reported by a few subjects and those by many subjects and experimenters. With these points in mind let us see the main facts that are known to us to-day.

Since Wertheimer's work (55) was the incentive for most of the later workers and discussion is still centered around his statements and theory, we start with his work. He says that by successive exposures of two stationary stimuli, separated by a short distance with proper time interval a good movement impression of the object is obtained. This is called the optimal movement. When the interval is made much smaller the two objects are seen as present simultaneously without movement. On the other hand, when the interval is much longer the movement is not seen but the object appears and disappears successively in each place. Between these definite stages there are transitional stages of intermediate type showing progressive changes from simultaneity through the stage of optimal movement to the successive stage. They are roughly divided into bimembral movement, unimembral movement, and intramembral movement stages. By the bimembral movement is meant that the first object "a" moves a part way toward the second object "b" and disappears; then "b" appears below that point and moves into its end-position. The distances they go vary from almost the entire distance between the two objects to a very small part of that distance. By unimembral movement is meant that one of the two objects alone

moves and the other stays still in its place. The intramembral arises when one or both objects have some kind of movement within themselves without exchanging places. Existence of these forms of movement are generally accepted although different authors differ greatly as to the conditions which produce them.

Wertheimer says that in these movement phenomena the spatial as well as temporal relations of the two objects depend upon the length of pause more than anything else. According to him the optimal movement occurs at a pause of about 60 σ, the simultaneity at 30 σ, and succession at 200 σ. We must remember that he used very short exposure times equally for "a" and "b" and different times for different pauses. While Dimmick (8) found that his subjects could see the optimal movement at a pause of 90 σ, simultaneity at 30 σ, and succession at 150 σ using the exposure time of 30 σ all through and the same stimulus patterns, namely, parallel lines and lines meeting at an angle.

Quite in opposition to Wertheimer and Dimmick, Higginson (25), McConnell (40), and DeSilva (6) independently came to the conclusion that it was impossible to set up a significant correlation between any one temporal interval and the full movement, for it occurred in a very large per cent of the exposures in all intervals. Also a clear insistent movement occurred under phenomenal simultaneity, at zero pause, and by sudden subtraction or addition of one stimulus object. Besides, the subjective attitude could change the full movement into any other form. Grant and Vogt (18) found rather few reports of optimal movement at a pause of 60 σ.

Earlier than these men, Benussi (2), Hillebrand (28) and later McConnell (40) found that the optimal movement was obtainable at zero pause with much longer exposure times than Wertheimer used. Benussi obtained much wider limit for the optimal movement where Wertheimer would see partial movements and stressed the influence of subjective conditions like predisposition and volition. He also did not agree with Wertheimer in considering part movements as developing stages of optimal movement but thought that they were different experiences qualitatively.

Most recently Waals, a nerve specialist and, Roelofs, an eye specialist, of Amsterdam published a very extensive work (52, 53) on visual apparent movement. They classify the phenomena quite differently and define terms quite differently. We need to state briefly their classification here. Their optimal movement or ideal movement as they call it, is defined as follows: the line appears in the left side of the visual field without movement and stays there for a moment and then moves towards the right where it stays for a moment and then disappears without movement. The mere loss of identity of "a" and "b" is the end of optimal movement and becomes the sign of simultaneity whether movement is present or absent. This should not be confused with physical simultaneity which is a different thing. The succession stage sets in with the perception of a temporal-spatial-gap between "a" and "b", but the pure succession does not arrive until no movement is seen. This latter part is equivalent to the older meaning. When "a" and "b" do not disappear together the line which disappears first disappears in the direction of the remaining line. This is "Erlöschbewegung". When "b" is exposed while "a" is still present, "b" seems to have come from the region of "a". This is "Auftauchbewegung". Wertheimer's bimembral movement may be nothing but these two movements combined, and his unimembral movement may be either of these. The intramembral movement is not especially separated but they recognize the existence of some kind of movement by the name of shimmering or trembling. Flicker, on the other hand, is specially mentioned as existing with the optimal movement in its borderline stages. Flicker means a sudden losing and regaining of light as the object moves. These forms of phenomena do not always exist in pure forms but two or three of them may exist simultaneously.

Results obtained by their particular method and arrangement necessitated this new classification, which will be found significant for the authors' interpretation of the phenomena. Having the benefit of more advanced apparatus and knowledge of past works, they pointed out the prejudice of earlier workers against long exposure times and long positive and negative pauses, with

which the stroboscopic phenomena would be impaired, and they applied a great variety of lengths of exposure time (111 σ to 1000 σ) and pauses of negative as well as positive values (—888 σ to + 1000 σ). Their results accordingly are of wide range. (We shall use terms as they defined them when we discuss their results.)

The ideal movement can be brought forth with a small negative pause (—22 σ), a zero pause, or a small positive pause (44 σ) provided the exposure time of the first and second objects have certain lengths. For all these pauses much longer exposure times of the first object are necessary while the second object can remain as short as 111 σ. For simultaneity the short exposure time of the first object is very important. The successive stage is brought forth quickly with exposure times of the second object as short as 111 σ or 222 σ with a pause of 666 σ but the pure succession does not arrive till it becomes 333 σ with a pause of 888 σ. A difference of 111 σ in exposition of the two objects is sufficient to produce "Auftauchbewegung" and an increase of this difference with a longer exposure time of the second object favors this movement phenomenon. The "Erlöschbewegung" is favored by small negative pauses with long exposure times of the first object prior to the appearance of the second object, and also by the longer exposure of the second object after the first has gone. Flicker is still very slight with a pause of 44 σ and becomes very clear with a pause of 111σ.

According to these findings it is clear that the pause is no longer of the first importance for the optimal movement. Instead, the exposure time, especially long exposure of the first object, is necessary while the long exposure of the second object is injurious, with rather a wide limit of pause. The flicker seems to be a product of the small positive pause. Previous to their discoveries the importance of the length of exposure time was pointed out or suggested by more than a few people. These discoveries upset Korte's law (35) partly.

The psychological state of affairs is, the two objects "a" and "b" are given successively as stimuli; it is felt that "a" is seen first and "b" last; between them the movement from "a"

to "b" is seen. What is there besides "a" and "b"; what happens in the interspace; what becomes of "a" and "b"? Phi is the word used by Wertheimer here to denote that something that binds "a" and "b" inseparably. In the optimal movement stage the phenomenal content of Phi is given through subjective completion of the space-time-continuous interspace, which is not present objectively. There are also cases where Phi is present when no visual subjective completion is in the movement field; there is movement only without reference to an object. When attention is concentrated on this empty space, the impression of movement is much stronger and yet nothing of visual quality is present. Sometimes Phi is so strong, especially with novelty of arrangement of the objects, that subjects can not give any account of the object and the direction of movement although they are positively sure of some strong movement. Unlike the ordinary illusion which would be badly injured by attention on the critical point, this Phi is strengthened most by directing the attention on the movement field. Phi is not influenced by different colors of objects but it is greatly influenced by "Einstellung" (predisposition). In the experiment with the stimulus pattern in which a short line makes an oblique angle of about 30° with a long horizontal line at the center and on the right upper side of the horizontal line, it results in a rotation to the right. This movement may persist when the angle is more than 90° provided the angle is progressively enlarged, and at 120° the rotation to the right is still seen and some individuals may see it even at 130° or 170°.

In the optimal movement stage the impression is of one object in motion no matter how different the colors or sizes used for the first and second stimuli. In other words, identity of "a" and "b" is very forceful and there is no room for inference to come in. Wertheimer asks if this identity is equivalent to the real event of movement, and if they belong to each other essentially or are necessarily combined. He finds the latter would be the case, for the identity disappears earlier than the movement impression as he shortens the pause little by little from the border line

of the optimal stage. Similarly, he finds the movement impression appears before identity is felt, as he takes gradual steps from simultaneity to the optimal stage. Throughout various kinds of object patterns the same is found and has made him conclude that the movement impression is separable from identity.

It was not Wertheimer alone who discovered Phi. Schumann (42) while demonstrating the windmill rotation noticed that there was at times no object but something just moved over and this something did not mean any conscious content brought about by the retinal stimulation. He said that when two successive and spatially separate visual impressions fell on the eye there was a clear impression of movement and this was a central process. Lasersohn (36) said the same thing.

Dimmick (8), Dimmick and Scahill (9), and Dimmick and Sanders (10) advanced a step further than Wertheimer and said that the pure Phi is something moving, detached from the object, but closely related to the phenomenal filing of the interspace. The gray flash filled the movement field and it is the psychological correlate of Phi. Grant and Vogt (19) seem to have confirmed Dimmick's gray patch by a filmy pathway or vague film between the two stimulus objects. But their vague film has always the color of the object.

Steinig (46), in Schumann's laboratory, undertook a work specially to find out about " Zwischenstadien " which Wertheimer did not say much about and discovered their presence. It was observed that images of perception wandered through the visual field although objectively only the beginning and ending were shown. However, these " Zwischenstadien " were not always present very definitely in the inanimate simple objects and in certain conditions though they were positively sure and clear in more complex figures and animate pictures. Steinig used 120 σ for the pause and 50 σ for the exposure time. The same sort of study was done long ago by Grützner (20) and Dürr (12) who presented the beginning and ending of a leaping boy in optimal time and tried to see how large a gap could be filled by cutting the pictures bit by bit. Dürr found that the movement experience

might be gradually destroyed by progressive elimination of successive phasal postures so long as no corresponding change in rate of presentation was made.

Higginson (25), McConnell (40), and DeSilva (6) agree with Wertheimer in regard to the possibility of non-qualitative characteristics of the visual movement, but disagree with Dimmick and his co-workers in considering the qualitative aspect of the movement experience as the psychological correlate. Instead, they simply take it as one of the visual resources directly aroused on the occasion by stimulus objects and apparently utilized at times by the individual in apprehending the visual movement. This view was strengthened by Higginson's third work (27) with various colors for stimuli and background, and also by Squires' work (44) of similar type. The extensive application of colors revealed another disagreement with Wertheimer, which was quite serious for his theory. That is, there is always the meaning that it is an object of a certain hue which moves even across the entirely unfilled visual gaps. Higginson says that the movement is not in any way to be separated from the hue of the object. Moreover, a mere change in hue is sufficient to change the character of the movement, which fact may mean that a mere loss of identity between the two members interrupts the continuity of movement. These findings of Higginson led him to regard quality as a factor as important as Wertheimer's three factors, time, distance, and intensity. Benussi (2) and Wittman (56) attack Wertheimer on the same point, saying there is an objective meaning even in the pure Phi; movement is not to be separated from the thing moved.

Waals and Roelofs (53) also insist upon inseparability of movement from the objective meaning. Their true optimal movement must be seen as clear displacement of one object which is felt as sensory. If there is a little gap and that gap is subjectively crossed, then it is no more a true optimal movement, but pseudo-optimal movement which they did not explain. This strict oneness of the object in the optimal movement and the inseparability of the movement from the sensory object indicate that they deny the pure Phi except in their definition of it. To favor this move-

ment, they say, the subjective conditions are not very essential. The movement is so real and positive that differences in color as well as differences in attitude or " Einstellung " do not make any change in the presence or absence of the quality of movement. On the other hand, DeSilva (5) and Benussi (2) stress subjective determinants as equally important with the objective conditions.

Along with the study of effects of various fixation points Waals and Roelofs used two distances, 10 cm. and 45 cm. and found that the movement impression with the greater distance was different from that with the shorter distance. A subject sees the movement more consistently without a fixation point in the small distance but less consistently in the long distance where the influence of subjective conditions is stronger. This part of the study taught them that seeing of the apparent movement was a problem of relative localization of the object concerned during movement.

A comparison of apparent movement and real movement was tried by Dimmick and Scahill (9) and DeSilva (7). The close resemblance of the two impressions caused the former to try various methods. They set up a subjective attitude and a stimulus attitude in their subjects by different instructions and came to the conclusion that the two stimuli could be distinguished after much practice, and that the distinction was not in perception as such but in the process pattern of movement. By this they meant a filling of the movement field with a gray flash and the difference was merely in the relative distribution of various degrees of intensity within the gray flash. DeSilva's discovery was about the same, only put in a different way. He says the movement impression has two attributes, namely " movingness " and " vehicle-of-movement ". The former is Phi and the latter seems to correspond to the gray patch of Dimmick. The chief distinction between slow and fast real movements and between real and apparent movements seems to lie in the relative clearness of the " vehicle-of-movement ". The main stimulus variable of the real movement is the velocity: when it is slow the Phi and the moving object possess a high degree of clearness. The best conditions for apparent movement are short distances, short pauses, and to

a lesser extent long exposure times and increase in the light intensity. Effects of subjective determinants like attention, attitude, habit, and predisposition are marked. Since obscurity is the characteristic of the fast movement of both kinds, the complete account of perception of movement is beyond our power.

Theories:

We can roughly divide the theories into those which stress peripheral conditions in the explanation and those which go beyond the peripheral to seek the cause in the higher centers. In the former group we classify the following men: Vierordt (51) insists that stroboscopic phenomena are purely sensational in character because of the function of the sense organs for space; saying that the cutaneous and visual organs always give us only movement impression from the moved objects. Stratton (48, 49), being unable to agree to make visual movement either a sensation or a perception, discovered something that is neither. Perception of movement is only the perception that a sensation is changing its space relations. Motion itself furnishes a decidedly favorable condition for appreciating such differences of space relations, and the mind becomes accustomed to this manner of interpreting all rapid change; we interpret it instinctively as movement. Aubert (1), who found the same results as Exner, says that if an object is to appear as moved there must be a certain space on the retina between the two stimuli in one second and the movement impression is determined by the number of retinal elements affected. Triepel (50) inclines to believe that several visual cells converge upon one bi-polar cell and several bi-polar cells upon one ganglion cell. The discontinuity of the excitation of the visual cells caused by the moving object is thus overcome by a "flowing together" in the inner layer. Since the retina is an extension of the cortex it may be assumed that the image of movement is directly created in the retina and then rises into a conscious perception by associative connections in the occipital lobe. Fischer (16) believes the after-image to be essential to the stroboscopic movement and states that in order to induce movement of an object artificially it is necessary and sufficient if we

recognize phases of movement in close succession in time and not too far apart in space.

Higginson (25) says that non-visual resources as verbal kinaesthesis, pressures around eyes and face, and certain rhythmic activity of bodily members, feet and hands, are utilized to a great extent in the apprehension of movement; finally concluding that the visual apprehension of movement under discrete retinal stimulation is a form of abstractive perception determined by stimulus, receptor and central organs; the degree of abstraction depending upon the availability of experiential items and upon the relative contributions of environmental and of organic factors. A little later he (26) put a great emphasis upon the ocular movement as being one of the main conditions upon which the perception of visual movement depended, enumerating points in favor of an eye-movement theory and points unfavorable to Wertheimer's physiological theory. McConnell (40), finding results very similar to Higginson, came to the almost identical conclusion except that he excluded all bodily kinaesthesis from the conditions and said that these were mere incidents which may precede, accompany or even follow the phenomenal movement.

Guilford and Helson (22) obtained photographic records of eye-movements during the perception of the Phi-phenomenon. In spite of reports of eye-movements, strain, and kinaesthesis, the corresponding photographic records showed no evidence whatever of eye-movements of such significance, either in amount or direction as to correlate with the seen movement.

Stern (47) said as early as 1894 that the perception of movement was produced thus: there is the perception of a change in localization by an object, which is associated with the consciousness of identity, and leads to the assumption that the object itself has moved. This was his principle of phase comparison which could be either visual or kinaesthetic. The motion impression was really a complex put together of many familiar impressions and it was not any special sensation. He attempted an analysis of this complex and pointed out the three factors as responsible for the motion perception: (1) modification of stimulus, (2) flow of after-image, (3) eye-movement.

Hillebrand (29) applied his absolute localization theory for the explanation of stroboscopic movement. He says that apparent movement is not observed in the case of voluntary eye-movements. The stage preceding such eye-movements is characterized by a displacement of attention in the visual field or a displacement of the maximum of distinctness which results in a loss of position at one side of the visual field and a gain at another. The displacement of the visual field which is effected by paying maximal attention to a peripheral object explains how it is possible that in two successive moments we localize differently with one and the same retinal point. In case an eye-movement is actually made, the point of maximal attention becomes the point of fixation and the displacement of the visual field does not affect the absolute position of objects; only the relative position changes. An object localized in the median plane may assume a lateral position although we still refer it to its median position. The reason for this is that we are accustomed to do so and we are not accustomed to do so in the case of displacement occurring in the instantaneous period preceding the eye-movement and succeeding the attention shift.

Prior to Wertheimer's physiological theory there was in Germany a strong tendency to emphasize higher processes in the central nervous system though rather vaguely stated. Some of them are offered by Linke (38), Marbe (39), Schumann (43), and Exner (13, 14). Exner was the earliest of these and definitely anticipated Wertheimer. Exner obtained the movement by rapid successive stimulation of the two eyes separately. This could not be explained by peripheral conditions but by a specific physiological process in a hypothetical movement center in the central nervous system, which is immediately affected by the movement sensation.

Wertheimer pictured this specific physiological process more definitely than his predecessors and made the explanation of Phi purely physiological making the peripheral conditions of minor importance. Koffka and Köhler are very much in sympathy with him, and indeed the latter's hypothesis coming out much later represents the physiological theory of Gestalt psychologists.

Köhler (34) says as soon as the first stimulus works there arises always a kind of pillar (Säule) of current into a higher field of the optic sector. Before this pillar disappears the second pillar of a similar kind arises from the second stimulation. Under these circumstances the " Kräftegruppierung " in the whole system, in order to keep a balance, turns the two current pillars under the psycho-physical level in the direction of each other, so that they unite into one process. If the first current pillar is fully formed and the second is just beginning, then the second process is pulled into the path of the first, where it reaches a psycho-physical level. Now the first stimulus ceases to work and the second alone is left to work; this pillar now tends toward the balanced position and finally its proper position is attained. The final position is possible only in the absence of the first stimulus. Thus we see the full movement of one object from the first place to the second, which is really composed of displacement of the first and the second stimulus objects. If the displacement is not too quick this process is conducted to the chemical exchange which corresponds to the color of the object, whereby a moved object is seen in a suitable form and color. If fusion of both current pillars is impossible, the displacement of one or both objects results on the same principle and we see the part movement.

Koffka (33) reminds us that the visual field under normal conditions is always a totality. The retina is being constantly stimulated; any shift in the retinal pattern must of necessity involve the whole retinal extent. Various parts of the retina do not function independently; any change in energy relations at one part will be reflected in all other parts by a change in functional activity. He did not forget to bring out the importance of the subjective conditions like attention and attitude. He says that all phenomena, just as their physiological correlates, depend upon the totality of existing conditions. If before application of a stimulus the subject has a definite setting of his attention, then his entire visual field is influenced by this setting. Let the objective field be entirely homogeneous and concentrate your attention on the fixation point then your visual field will be distinctly non-homogeneous. This non-homegeneity of the visual field influ-

ences the form of movement. Zietz and Werner (57) found a fact which confirmed this totality function by accompanying rhythmical or arhythmical tappings to stroboscopic presentations of various figures. It was found that auditory stimuli exerted a modifying influence upon the perception of visual movement to the extent of changing the course of visual movement. Therefore they concluded that the movement is the dynamic function of the entire organism.

The only criterion of the optimal movement for Waals-Roelofs is the perception of a single line, which must depend upon the fact that both lines occupy a common place during a part of the perception-duration (Wahrnehmungsdauer). The greatest riddle is that we never see " a " disappearing in its own place and " b " appearing in its own place. Therefore the cause of visual apparent movement ought to be sought in the existence of the mechanism which brings about the phenomenon that the object corresponding to the second stimulus is visible in a different place and the object corresponding to the first stimulus disappears in a different place, each being under the influence of the other. Thus analyzing the optimal movement we see it is nothing but a combination of "Auftauchbewegung" of " b " and " Erlöschbewegung " of " a ". In explaining these two forms of movement they hardly touch the physiology of the cortex as such, saying that no established foundation is obtainable for any assumption concerning it. They assume, however, an existence of a certain psycho-physical process which lies in the foundation of perception and which rises and wanes in strength and manifests itself subjectively in brightness. It possesses two components, one which is the foundation of light impression, and the other which decides the visual localization of this light impression. Both may not take place in the same part of the brain. There are two variables which they used as the main instruments in the explanation, perception time and perception duration. Perception may not take place immediately following the application of a stimulus; the time elapsed between the application of a stimulus and the beginning of perception is called " Wahrnehmungszeit " (perception time). The actual duration of perception is called " Wahrnehmungsdauer " (perception duration), which may not

exactly coincide with the cessation of stimulation. Both are very indefinite, depending upon many factors like light intensity, duration of stimulation, attention, individual difference, and the inhibiting effect of the stimulus working at the same time.

It is clear that the "Auftauchbewegung" (of the second object) begins after the presentation of the second stimulus, and ends when the second object is seen in its normal place. The "Erlöschbewegung" (of the first object) surely occurs after the first stimulus is taken away, after the presentation of the second stimulus, and its end comes with the invisibility of that object. If perception ends with the cessation of a stimulus there would be no "Erlöschbewegung". The localization change occurs during this period when "Erlöschbewegung" is perceived. As long as a psycho-physical process remains in all its components on a certain height after the cessation of the stimulation, there will not come a change in localization and accordingly no "Erlöschbewegung" will be seen. It must be that the psycho-physical process of the first stimulus decreases after the stimulation ceases, and the psycho-physical process of the second stimulus influences the localization of the first stimulus during the period when the subjective brightness of the first stimulus is quickly waning. It is beyond question that the changed localization is due to the waning intensity of the psycho-physical process concerned. Then we can say that the "Erlöschbewegung" of "a" occurs because the psycho-physical process of "a" decreases in intensity so that "a" loses its normal position under the influence of the simultaneously present psycho-physical process of "b", and disappears in the changed place. Similarly the "Auftauchbewegung" of "b" occurs because the psycho-physical process of "b" is not yet strong enough to resist the influence of the simultaneously present psycho-physical process of "a", so that "b" is seen first in the different place. The whole mechanism is now revealed to be the function of the "Wahrnehmungszeit" and "Wahrnehmungsdauer", both of which are under the influence of many factors. Out of the most complicated interactivities of these factors "Erlöschbewegung" and "Auftauchbewegung" are produced and compose the ideal movement phenomenon when conditions are proper.

METHOD

All the experiments were carried on in the dark room using the Eastman kodascope and the silver-gray screen. The distance between the kodascope and the screen was kept constant so that the size of the lighted area on the screen was always 34 cm. by 25 cm. The subject was seated at a distance of six feet from the screen and was facing it at an angle of about 5° to the left from the center of the lighted area and the screen was at a little lower level than the eyes if it was not on the same level. The pictures on the film were carefully drawn by hand with India ink under the magnifying glass or photographed. The background was always white and the picture was black most of the time. The size of the pictures and their relative positions of exposure on the screen were varied according to the arrangement in each experiment. Their exact sizes and their relative positions and the order of exposure are stated for each experiment in the accompanying table.

The Eastman Company says that this kodascope runs at the speed of 16 sections of the film per second. Our repeated tests showed more than that. Averaging all our measurements at different times we found it runs almost 19 sections per second. Therefore, despite the manufacturer's statement, 18 sections per second were used as the speed of the machine in all our experiments. This speed gives the figure 60 σ for the length of exposure time of each section of the film. For the sake of brevity, and freedom for those who desire to use the speed stated by the manufacturer, all times used in this work will be designated by the number of sections of the film instead of by sigma. The exposure time for a single picture was one section, 60 σ, according to our measurement, as we did not have the same picture on more than one section of the film in succession. In fact, the speed of our machine was fixed and the exposure time of each section was not adjustable so as to make it 30 σ or 80 σ. The length of

pause between two successive pictures was varied by using different numbers of blank sections in succession. This also could not be adjusted in a finer ratio than doubling, trebling, and so on of a section of the film. However, the 60 σ was the period that each section of the film stayed in one position although it was not the true exposure time. The disk of the kodascope is divided into six equal sectors, each of which is, therefore, of the size of 60°. The alternate sectors had openings toward the edge through which the light was permitted to pass on to the mirror, which was situated in the back of the film. The mirror reflected the light on to the screen passing through the transparent film and the lens in front of the film, so that any picture on the film was enlarged by the lens. The other three sectors had no opening so they shut off the light. The speed of rotation of this disk and the speed of the passing film were identical. Therefore the period of 60 σ was divided into six equal periods by the three open and three closed sectors of the disk, thereby throwing the same picture on the screen three times with equally short interruptions. During the third period of closed sector the film has moved and the new picture was brought into the exposure field and remained there for 60 σ. These periods of open and closed sectors went on regularly as long as the machine was working whether or not it was an exposure period or a period of pause. One does not notice any change of opening or closing since the duration of each open or closed sector was only 10 σ. It follows that when a bar is shown on each section of the film there is a pause of 10 σ between exposures. If one section intervened there is an interval of 70 σ, if two intervened 130 σ and so on.

The outstanding difference in this work from previous works was the repeated exposures of the picture instead of a single exposure. However, the number of the repetitions was not used as the standard for each series. Since the entire length of the film per series and accordingly the time to run it would vary greatly for different lengths of pause used, we kept the length of the film approximately constant, and when it came

to the question of comparison of two movements or speeds, the entire length of each series did not exceed 40 sections. It would take about two seconds to run a series and this would allow the picture to be shown on six sections of the film even in the series with the longest pause. In order to avoid any influence or suggestion of the preceding series, the order of exposure of different series was carefully arranged not to be in an ascending or descending order of any sort, or so far as possible, not to be in groups of similar pictures. Besides, there was a few minutes rest after each series for reporting the observation and relaxing the tension.

The subjects were mostly undergraduate students of both sexes who were at the time taking a course in psychology but inexperienced in experimental work of this kind. The number of subjects used in each experiment was not uniform, nor did the same subjects serve throughout the experiment owing to the fact that the work was carried on over a long period of time, during which new phases of the problem developed. The same series was repeated at least twice to each subject, who was previously familiarized with the kind of work by other pictures. The instruction was given orally before each sitting and the report of the observation was recorded by the experimenter immediately after the exposure of each series. The instruction was as follows: "I am going to show you some pictures on the screen. Watch carefully and tell me all that you see. Each series of pictures is very short and after each series I shall stop the machine and let you describe all that went on on the screen. I want to know every thing in detail. This is not a memory test, however, so you do not need to worry about that and I am sure the pictures are simple enough for you to remember for a short time any way. Each series is different, so do not expect anything in the later pictures like any you have seen previously. Each time you are shown a different thing. Just be seated comfortably and easily and watch the screen carefully. Do not move any part of your body during the exposure because that may disturb your observation."

The subject's head was not supported or restricted in any manner to keep it absolutely still, nor was there any fixation point for the eyes. He was free except that he always sat on the chair set at the same place. As is common with untrained subjects they were unable to give details of their observations probably, because of the very simplicity of the objects, I had to bring out details by asking questions, which in turn, would bring out suggestions as to how the pictures should be seen. This is not desirable of course. Care was taken to ask as little as possible and only when the student was found helpless without some encouragement.

EXPERIMENTS

The experiments were devoted to three main problems: A. back and forth motion, B. rotary motion, and C. speed comparison. This grouping is made for the convenience of treating the results of a widely scattered, complicated and overlapping nature. They are fundamentally the same and supply the clues to solve the same problem, except perhaps, that the last group which was developed while former experiments were being carried on, has some special elements of its own.

A. *Back and Forth Motion:*

Experiment I
(7 Series)

Procedure: A bar was exposed in two different places alternately and repeatedly in such a way that the two successive exposures would form an angle of 45° opening toward the right above the horizontal bar. This angle distance was kept constant all through the seven series of Experiment I, but each series had a different length of pause between successive pictures, ranging from one to seven sections of the film. For brevity we designate each series of pictures by the number of sections used for a single pause in that series as P.1 Series, P.2 Series, and so on, by which we mean the series with pause of one section, two sections, and so on.

Results: The results show three forms of motion: 1. the real continuous motion back and forth between the two places of exposure; 2. the back and forth motion with the bar distinctly disappearing in the interspace; 3. the bar just flashing on and off in two different places alternately. Each group includes several kinds of observations. Some subjects were very uncritical and contented themselves by saying, "It is moving back and forth evenly and continuously and I see it perfectly; nothing is different from the movement of an actual object."

Some saw the perfect movement during the observation but afterward only the two extreme positions stood out clearly. Some others said that they saw the bar only in the extreme places and not at all in the intermediate space but the bar was not disappearing; it got faint or blurred by quick motion; or it was like jumping from one place to another and the bar was seen only in the end positions where it stayed longer. All these observations are grouped into one as real continuous motion, equivalent to Wertheimer's optimal movement and we call this group Type I Motion.

The second group includes ever so many degrees of disappearing. The bar moved back and forth between the two places with disappearance in the middle part of the distance, or the bar moved part way and disappeared and when it was seen again it was in the next end position and moved back and disappeared before it took the first position. The amount of the movement in this group ranged from very little to almost the entire distance. It was impossible for some subjects to state where the bar disappeared or how much it moved before disappearance, but for some subjects it was not very difficult. The fractions they used were ½, ⅓, ¼, ⅙, and ⅛ of the whole distance, or sometimes the width of the bar was used to show the amount of little movements. Motions in this group may correspond to Wertheimer's bimembral and unimembral movements. We call them Type II Motion.

The third group includes two kinds of report, that the bar merely flashed on and off alternately in two different places, and that the feeling or idea of motion was suggested by the flashing on and off though the bar itself did not seem to have moved any distance. This group is called Type III Motion. It may include Wertheimer's intramembral movement and pure succession.

Grouping the various observations as stated above Table I and Curve I are obtained, according to which Type I Motion was observed in 82 per cent of cases in the P.1 Series and 66 per cent in the P.2 Series. After this the percentage dropped suddenly and then rather gradually decreased till it came to the P.5 Series,

beyond which no more Type I Motion was observed. Type II Motion was observed in both extreme series almost equally often. It increased till it came to the P.3 Series and then began to decrease. Its behavior was opposed to that of Type I Motion till its maximum point was reached and then opposed to that of Type III motion. If we take 50 per cent as the critical point for any type of motion, it seems that the Type I motion has its critical point between the P.2 and P.3 Series, the Type II motion between the P.3 and P.4 Series, and the Type III motion between the P.4 and P.5 Series.*

Variation of individual subjects is very noticeable. There were a few extreme types: one subject denied Type I Motion entirely; one saw some kind of motion in every series and none of Type III; three subjects saw Type I and Type III Motions mostly and only very little of Type II; one subject saw Type I Motion in the P.1 Series in 100 per cent of cases but none after that while another subject saw it in 100 per cent of cases as far as the P.4 Series. Five subjects saw Type I Motion in the P.1 and the P.2 Series in 100 per cent of cases; eight subjects saw it in over 50 per cent of cases in the P.2 Series and only two subjects in the P.3 Series. Five subjects saw motion of Type I or Type II to some extent in all series; five subjects saw Type II Motion in over 50 per cent of cases in the P.5 Series. In spite of the extreme cases the tendency of the majority agreed with that of the average.

Variation in the amount of motion in Type II was also great but as a whole the bar moved a greater distance in the series with a shorter pause and as the pause became longer the amount of disappearance increased. In the P.1 and the P.2 Series the motion of a quarter of the distance was the least distance, and in the P.5, P.6, and P.7 Series the same fraction was the longest distance that the bar moved before it disappeared. The P.3 and P.4 Series showed the greatest possible variety from very little to almost all. Another peculiarity is that the disappearance of the bar was almost always in the middle part of the entire distance

* It will be recalled that in P. 1 the stimulus lines were separated by an interval of 70 σ, P. 2 by 130 σ, etc.

in the P.1 and P.2 Series and it occurred more often in the latter part of the distance in the P.5, P.6, and P.7 Series.

Besides these motions remarks are made by various subjects regarding the appearances of the interspace and the bar. They are: 1. The space bounded by the two bars seems darker or gray; it is hazy because the bar is running across it. 2. The space near the bar at the top and at the bottom is darker and the central part is light. 3. The space is brighter than the outside of the boundary. 4. The space is just the same as outside during the observation but it is felt gray afterward. 5. The space is just the same as outside. 6. The bar is clearly seen in the extreme places and is blurred in the interspace. 7. The bar is clearly seen all the time. 8. The bar is more distinct in the top or bottom position and faint in the other position. 9. The bar is seen clearly in more than two places. 10. The bar is seen most clearly in the central position and faintly in the top and bottom positions. These remarks were not constant. The same person may say one thing at one time and a contrary thing at another time for the same picture. Some subjects saw certain of the phenomena as indicated above all of the time, others gave more varied reports of what was seen. Tabulating all these remarks for each series of pictures we get some tendency peculiar to it as well as to each subject. There are three subjects who had nothing to remark about the space but that the space was just the same as the outside space while there are two subjects who never saw the clear space. All others, six subjects, saw different things which were at times contrary to each other. About the first three subjects we can not say much. There seems to be no relation between the clear space and the types of motion for them because they saw the three types fairly evenly. The second two subjects are rather different from the rest. One of them saw the uniformly dark space always as long as he saw Type I Motion (P.1 to P.4 Series), during which he reported that the bar did not stop at any particular place as the ordinary moving object does not, and was clearly seen all the time. About the time that Type I Motion changed into Type II Motion he began to report that the bar was seen clearly in the central space and

faintly in the top and bottom places three times out of five and saw it clearly in the end-places only once in the P.6 and P.7 Series. Consequently he was not sure about the space being uniformly dark, though he never felt it as light as outside. It is to be remembered that he is the one who never observed Type III Motion. The other subject did not show such coincidence in her observations though she saw the motion in every series and less non-motion than the average.

The majority of the six subjects showed more irregular and contradictory observations from which we can draw the following conclusions: The gray space was observed by all of them at least once in the P.1 and P.2 Series and by more than half of them in the P.3 and P.4 Series. Then the percentage decreased suddenly, when the observations of clear space increased remarkably and continued. The report that the space near the bar was dark and the middle part of the space was light seems to go parallel with that that the space was brighter. It was most frequent in the P.2, P.3, P.4, and P.5 Series although all of these were reported uniformly dark at different times.

Two subjects customarily saw the bar distinctly only in one place, top or bottom and faintly in the other at least once in all

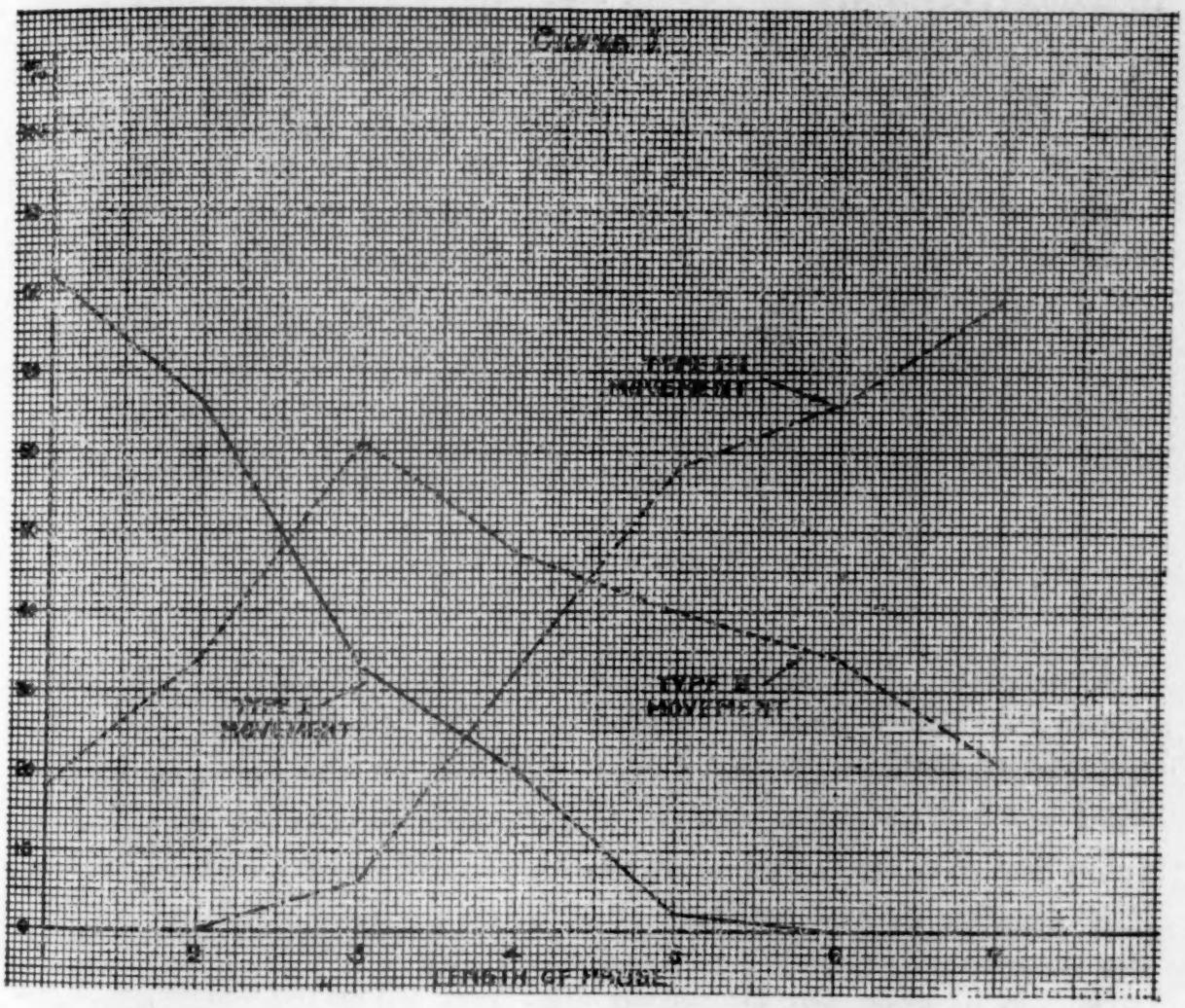
TABLE I*

Stimulus pattern: (See Fig. 1 on page 89).
Size of the bar: 18 cm. by 1.5 cm.
Distance: 45°.
No. of subjects: 11.

Length of pause	1	2	3	4	5	6	7
Type I Motion.....	82	66	33	20	2	..	..
Type II Motion.....	18	34	61	47	40	34	21
Type III Motion.....	..	..	6	33	58	66	79
Total number of records	*22*	*44*	*66*	*55*	*55*	*44*	*42*

* The ordinary figures indicate the percentages and the italic figures indicate the actual numbers of cases. When there are no figures in the respective places in the table it means that there were no cases under the particular items in the particular series. These apply for all the tables following.

pictures, except in the P.1 Series. These same subjects saw the bar in three or four places equally clearly at times in certain series. Their descriptions show that the bar seemed to them doubled in each end-place and made it look like three or four bars. Most subjects saw the bar clearly in the end-places only, and faintly in the interspace where good movement was present.



Experiment II

(6 Series)

Procedure: The general scheme was the same as in Experiment I except that the angular distance between the two lines was 90° instead of 45°, facing toward the right and down. The number of the subjects varied between 22 and 27 in different series.

Results: As a whole the results are very much like those of the previous experiment. The conspicuous points of difference

are, however, significant as to the variation made in the stimulus pattern. The Type III Motion was observed even in the P.1 and P.2 Series and as a whole its percentages increased. The Type I Motion was very infrequent in the P.4 Series. In Type II Motion a smaller fraction, $^1/_{10}$ was added to those given in the last reports.

The new forms of motion were reported very few times but they may be equally significant. The horizontal bar moved down to the vertical position and disappeared there, then it was in the horizontal position when it reappeared and repeated the down motion each time. Or the vertical bar moved up to the horizontal position and disappeared and reappeared in the vertical position to move up. Each type of movement was observed in all pictures almost equally often. The same subjects tend to see these motions repeatedly. Another noteworthy remark was of the jerkiness of the movement which was reported more or less in all series but most frequently in the P.3, P.4, and P.5 Series.

Experiment III

(7 Series)

Procedure: The bar was exposed in two parallel vertical positions alternately and successively. The distance between the two positions was always 2 cm. The size of the bar was 16 cm. by 1 cm. The pause between successive exposures was varied from one to seven sections of the film in different series as before. The number of the subjects used in this experiment was 18 for the most series and 7 for a few of them.

Results: Compared with the last two experiments the disappearance of the bar in the interspace was noticed much earlier; Type III Motion was reported more often as a whole than in Experiment I; Type I Motion was observed even in the P.7 Series but it decreased almost equally from the P.1 Series to the P.2 Series as well as from the P.2 Series to the P.3 Series. The critical points for Types I, II, and III, however, were not different. As a whole the general progress of results was less irregular than that of Experiment II.

Other remarks which became very frequent in this experi-

ment were that the bar was rotating on its own axis as it went back and forth sideways, and that the bar was going in a circle drawing a vertical tube in the air or in an arc, concave or convex toward us. Both were most frequent in the P.1 and P.2 Series and then suddenly decreased. Contraction and expansion of the bar as it disappeared and reappeared was reported very often in the series where the pause was long, and gradually decreased as the pause became small and almost disappeared in the P.1 Series. Less frequent reports were made concerning the jerky movement and the gray interspace, the former being most frequent in the P.4 Series and the latter in the P.1 Series. There were a few reports that the ends of the bar appeared before the central part or that the central part of the bar remained till the last when it disappeared. This was observed especially in the P.5 and P.6 Series. The report of intramembral movement became marked here. It was said that there was some movement that was very hard to describe, besides the flash on and off.

Experiment IV

(3 Series)

Procedure: The exposure places of the bar were parallel horizontal instead of perpendicular, with all other things similar to the previous one excepting that the number of the subjects was 19 all through.

Results: The experiment was not carried on very far in this series but the tendency shows that Type I Motion is present in the P.1 Series perfectly and falls below 50 per cent in the P.2 Series, where Type III Motion appears suddenly in a large percentage of cases. Type I Motion continues to decrease rather fast after that while Type III Motion is prominent in the greater number of cases.

Experiment V

(6 Series)

Procedure: This is the same experiment as Experiment II except that the bars were in colors. The horizontal bar was blue and the vertical red.

Results: The general tendency was not very different in most respects from that of Experiment II, with a very few cases of rotation and contraction and expansion. The noteworthy difference was that in more than half of the cases in each series the observer perceived the bar as two different bars despite the type of motion. In fact, the number of the bars that they perceived was not essential to the type of the movement in this as well as in other experiments according to many reports. There were some movements that could not be discovered in one color arrangement. Whether or not the movement was of Type I or Type II, the blue bar alone moved back and forth and the red remained in the place, or the blue went a greater distance than the red, or *vice versa.* As a whole the blue had more motion than the red.

It did not seem very difficult to tell where color changes took place. In one set of cases the color often changed as the bar turned over back and forth as if it had two sides of different colors. In all cases the same color continued as long as the bar moved and disappeared with it. When the bar reappeared or the second bar appeared, the other color appeared with it and stayed with it till it disappeared. For instance, if the bar went the whole distance continuously the change of color occurred in the end-place; if it went a quarter of the distance and disappeared, the new color appeared with the reappearance of the bar wherever that was and stayed until it disappeared. Where the bar was not seen the color was not seen also and the interspace seemed empty.

Experiment VI

(9 Series)

Procedure: Two successive exposures of a bar in two different places without any pause produced the effect of no motion but simultaneity of two stationary bars, according to some earlier workers. The same thing was experimented with by repeated exposures of our pictures. That is, a picture of the bar in two different positions was exposed alternately 36 times, with no blank section of the film for pause. The relative positions and

the distance between them were varied to a certain extent. Table II will show the variations.

Results: Repeated exposures brought about great varieties of results. Simultaneity of two bars was reported in great percentages in all series, ranging from 55 per cent to 94 per cent, but very few of them were reported as non-motion. Therefore here simultaneity meant only that there were two different bars on the screen at the same time whether or not they stayed still or moved around. In other words, the impressions that the pictures gave could only be produced by two separate bars, and moreover the twoness of the bar was compelling in some cases where the perceived movement was incompatible with the simultaneous presence of two bars. For instance, the bar was two and the movement of each was back and forth at the same time. The subjects could not tell how it was possible on the same plane without hitting each other, nor could they describe how the bars looked in the interspace but they were sure about the movements and the two bars. Sometimes because of this incompatibility they hesitated to report two bars. Short distances do not seem favorable for the presence of two bars, the percentages decreased as the distance decreases in the two stimulus arrangements.

The resulting movements were of many different kinds and combined in various ways. The typical movement seems, however, to be the rotation of the bar on its own axis, which was present by itself or combined with some other movement. It was most often seen, over 50 per cent, in the medium angle distances and in all series of the parallel arrangement. When it was too near as at 10° or too far as at 90°, it was less observed. It was not very often reported but seems typical in this experiment for the bars to shiver, to tremble, or to move in an indescribable way. The back and forth motion was reported too frequently to ignore, especially in the angle arrangement of 10° it was very frequent even in its pure form. Non-motion impressions were very few as a whole and none in the shortest distances, 10° and 1 cm. which escaped being detected even by the most critical observers who always denied any movement. The conic

movement may mean that the bar, or bars in a few cases, is drawing a cone in the air in the angle arrangement or a tube in the air in the parallel arrangement. When the bar came to the top or bottom position it was clearly seen on the screen surface but in other places it was more or less obscure being away from the plane or out toward the subject. This movement impression was observed in almost all series of pictures and most irregularly so that no objective cause was easily attached to it. However, there was a little evidence that it would be less easily produced in the pictures with greater distances. Contraction and expansion of the bar was reported very seldom, while there were quite frequent reports of a jerky movement all through different series.

There were more reports saying that the bar became faint and dark alternately, or the bar had a blurred outline rather than that the interspace was gray. Only certain subjects said that the space was dark and the majority denied it saying that it was the passing bar that made the space look dark but really the space was light. The motion of the bar was more like jumping, chopping, or bouncing than the smooth up-down motion.

Experiment VII

(3 Series)

Procedure: A radius was exposed in 3, 4, or 6 different places evenly spaced around the center successively with the minimum pause of 10 σ. The order of exposure was from the top perpendicular position to the left continuously throughout the series of the regular length.

Results: The results showed such an uncertainty in the three-place picture that it was impossible to show them in a concise table. Some of the typical types of reports were: "Three bars separated by 120° seen; each is moving on the free end but doing nothing to each other." "Three bars are revolving somehow; can't tell how." "Two bars are going around, one taking all three positions in turn and I don't know the other. The whole thing is hard to tell." "Three bars jerk around or wiggling." "The top line flashes or rotates on its own axis and the lower

TABLE II

Size of the bar: 18 cm. by 1.5 cm. Length of the pause: 10σ. No. of subjects: 24.		Stimulus pattern: (See Fig. 1 on page 89).						Stimulus pattern: (See Fig. 4 on page 89).			Stimulus pattern: (See Fig. 5 on p. 89).
Distance		10°	20°	30°	40°	50°	90°	1 cm.	3½ cm.	9 cm.	2 cm.
Number of cases where bar was seen as	1	*20*	*11*	*7*	*5*	*3*	*3*	*14*	*11*	*3*	*4*
	2	*24*	*33*	*37*	*39*	*41*	*34*	*26*	*33*	*41*	*34*
Back-forth motion		32	14	16	16	5	14	13	6	6	..
Back-forth and self-rotation.		18	16	20	5	16	..	15	16	36	..
Conic motion		11	9	5	..	..	..	23	5	5	11
Conic motion and self-rotation..		5	5	5	6	..	..	..	..	..	..
Self-rotation alone		11	36	43	50	48	32	45	55	34	55
Some kind of motion		2	5	..	6	16	11	5	5	5	37
Flashing off and on		..	2	2	5	11	24	..	14	14	..
One bar in back-forth and other off-on		6	6	5	2	5	8	..	..	..	..
One bar in back-forth and other self-rotation		16	6	5	9	..	11	..	..	..	..

lines draw a cone." "Three bars appear and disappear in each place and no movement between them." Out of 45 reports 10 gave the definite direction of rotation, 8 of which were wrong.

In the four-place picture the going-around impression was more frequent but when it came to the question of the number of positions or bars and the direction of rotation there were still many errors and much uncertainty. The reason for the uncertainty was that the bar came and went too quickly. "Felt some motion but can't tell," was often reported. The four positions of exposure were seldom recognized, mostly three positions only being observed. "Two bars forming the 90° angle are swinging round," was often reported.

When the bar was shown in the six places equidistant around the center the correct observation increased suddenly, the counter-clockwise rotation of one bar occupying 70 per cent of 45 reports.

Experiment VIII

(5 Series)

Procedure: A long horizontal bar and a short vertical one were exposed alternately and repeatedly in such a way that the short bar met with the long bar at the center of the latter and formed angles only on the upper side of the horizontal bar. The size of the angles was varied by the short bar only. The pause between two pictures was always one section.

Results: The results showed most diverse kinds of motion. Subjects often could not tell what it was, especially at the beginning of the experiment. They seemed to get lost and did not know how to describe it. After thinking they often made remarks as "three things just flashing off and on"; "some kind of motion felt but can't tell what it did," and so forth. At times it seemed almost unjust to force them to describe it. Drawings were employed to describe their impressions as closely as possible. The Table III summarizes those results.

The general tendency is that when the shorter bar was perpendicular or nearly perpendicular to the horizontal bar the splitting and uniting type of motion was dominant and gradually changed to back and forth motion of various types as the angle

became acute on the left side. A subject reported that the motion could change its side according to where he fixated his eyes. If he fixated more on the left side of the picture, the motion on that side became clear and that on the right side became obscure

Table III

Sizes of bars : 22 cm. by 1 cm.
11 cm. by 1 cm.
Pause : one
No. of subjects : 15
No. of records : 30.

Kinds of motion \ Exposure position and angle-distances	a 50° b	a 85° b	a 100° b	a 105° b	a 110° b	Totals of each kind of motion
Splitting & uniting	30	33	13	17	7	30
Splitting repeated	10	3				4
Sliding out repeated	7					2
Streching out	7	3				3
Streching & uniting		3				1
Splitting & shrinking		3				1
*Stationary *Split-unite	3	10	3			5
Sliding up repeated	3	3		3		3
Sliding in and out	13	7	7	3	3	10
*Stationary *Back-forth	3		3	10		5
Flashing off-on or some motion	23	13	23	10	20	27
*Flashing *Strech-out		13	7		3	7
*Going down *Strech out		3	3	7		4
*Going down *Flap over		3	3	7	7	6
*Back-forth *Some motion			27	20	33	24
Conic motion on left side			7	3	3	4
*Going down *Shivering*			3	10	10	7
*Strech out *Stationary				7		2
*Going down *Sliding				3	7	3
Flap over repeated					3	1
*Stationary *Back-forth					3	1

and might look like just shivering, flashing off and on, or entirely unnoticed, and *vice versa.*

B. *Rotary Motion:*

In the preceding group of experiments it was discovered that the pause of one section between successive pictures gave the best continuous impression of motion and that the distance between the two exposure places exercised an influence over the impression. We now proceed further to investigate the effect of distance alone on the kind of motion obtained, keeping the pause of one section constant, with a few exceptions; and also, to try the effect of the successive impressions of distances, which lead us to the question of the rotary motion.

Experiment IX

(14 Series)

Procedure: A bar was exposed in two different places alternately with one end of it on the same point like a radius, so that the two successive exposures of the bar formed an angle, one arm of which was horizontal on the right side of the screen and the other was attached to it at the left end forming an angle opening upward. The angle was varied in each series from 180° to 50°.

Results: Table IV shows the summary of the results classified into the fewest possible numbers of items. As the angle increased in size the motion of the radius grew more "flapping over", "sliding in and out" or "flashing on and off", all of which meant that the bar was not moving flatly drawing an arc on the surface of the screen. The "flapping over" meant that the radius was coming out of the screen surface with the free end toward the subject and dropping into the next place. The "sliding in and out" which was most frequent at the 180° angle, meant that the radius slid alternately into each position from the center point. The "flashing off and on" indicated no motion of the bar itself, but an appearance for a moment in one place and then in another. In all these three forms the subjects reported that they did not see the bar anywhere except

in the final two places when the motion ended. They saw the real motion of the bar back and forth on the plane only in the small angles from 80° to 50°. In the back and forth motion over the larger angles the subjects were not very sure whether or not they saw the bar actually moving all the time, but it was not coming out of the screen as in the other motions. The conic motion was observed in all cases but more frequently between angles 160° and 70°, within which no angle was specially favorable for it.

TABLE IV

Stimulus pattern: (See Fig. 1 on page 89).
Size of the bar: 11 cm. by 1 cm.
Length of the pause: One.
No. of subjects: 15.
No. of records: 31.

Angle distance	50°	60°	70°	80°	90°	100°	110°	120°	130°	140°	150°	160°	170°	180°
Flapping over.....	3	3	13	13	29	49	68	71	74	68	61	65	55	35
Slide in and out....	..	..	..	..	..	..	3	3	6	13	13	26	29	45
Flashing off and on.	..	..	..	..	..	3	..	..	3	..	6	..	13	16
Back-forth motion..	94	94	81	77	61	39	16	10	10	6	13	..	..	..
Conic rotation.....	3	3	6	10	10	10	10	10	6	10	6	10	3	3
Indescribable motion.	..	..	..	..	..	..	3	6	..	3	..	..	..	..

EXPERIMENT X

(14 Series)

Procedure: This experiment was similar to the last one in all points except that the radius was exposed in three different places instead of two in the order from left to right starting always from the top perpendicular place. The third additional position was on one side of the center so that the other side was always left as the largest angle. The pause between pictures was one section always except where the longer pauses were tried in the largest angular distance only.

Results: The additional third exposure position made some change in the result from what we expected from the last experiment. We naturally expected the bar would flap over in the longer distances, but the results indicated that the flat movement was possible even over the 190° distance under these circum-

stances and consequently the clockwise rotation was reported at times in all series. This same impression was more favored when the largest distance was on the left side of the center than when it was on the right side. That is, the going-round motion impression was better obtained in the pictures that had the three exposures of the radius together on the right side of the center than when they were on the left side. With the first few impressions of the bar the clockwise rotation was observed in quite a few cases but longer repetition changed it into " flapping over " across the largest distance. When the motion was reported as back and forth, it meant more than one kind of back and forth motion and the middle position was often not noticed.

Lengthening the pause at the greatest distance helped the clockwise rotation a great deal while it hindered the conic motion in the pictures where the three exposures were scattered more evenly around the center. The longer pauses at the greatest distances made another change in the impression. The radius moved gently in the largest space. Instead of the sharp quick motion like " flapping over " or " shooting up " it hid behind something while passing there, or disappeared in the last place and reappeared in the top, or it went a greater distance than it actually had gone before its disappearance. (See Table V.)

After the necessary records were taken all series were repeated with an additional instruction. The subject was asked to try voluntarily to make it go all round without " flapping over." The effect of the voluntary effort thus given by the subject did not make any difference on the motion impression. The majority of cases showed no effect whatever in favor of the rotation. A few had a little favorable effect while another few had a worse effect, and the rest saw the same effect which they had seen before without special effort.

Experiment XI

(14 Series)

Procedure: The radius was exposed in four different places around the center in the clockwise order from the top perpendicular position. The angular distances between the four places were varied but one large distance was always kept on

Table V

Size of bar: 11 cm. by 1 cm.

No. of subjects: 15

Exposure positions & distances betw. them														
Length of pause	1	1	1	2 betw. c & a	1	1	1	2 betw. c & a	3 betw. c & a.	1	1	1	2 betw. a & b	3 betw. a & b.
Clockwise rotation	6	32	52	73	6	16	13	27	30	16	17	3	23	37
Cw. rotation changed to flap over	6	16	10	3	10	10	16	7	7	19	7	3	6	13
Flap over big distance	74	42	32	13	74	45	58	63	60	39	57	74	60	30
Disappear or hide at big dist.				10				3	3				3	13
conic rotation	6	10	3			3	6			6	10	13	6	6
Back-forth in various ways.	3				10	23	3			13	7	6		
Flashing off and on	3					3	3			6	3			
Total no. of records	31	31	31	30	31	31	31	30	30	31	30	31	30	30

the left side of the center. The pause was one section except in a few cases where longer pauses were tried with the largest distance.

Results: The clockwise rotation was increasingly observed as the largest distance became smaller and the sudden increase was seen at the 170°, reaching its maximum at the 150°. Uneven degrees of smaller distances did not seem to affect the motion of rotation very much. In the series where the greatest distances were 180° and 190° the increase of the number of exposure places from three to four did not help the impression of rotation. It inhibited it a little. Lengthening the pause in the largest distance helped the rotation to some degree and made the motion slower as it did in the last experiment.

Many subjects reported that the radius was clearly seen in three places instead of four and a few subjects reported it as two or none. The last meant that the bar was going around the center without stopping at any particular place. They saw it go around smoothly. Occasionally exposure in five or six positions was reported. The cases where four places of exposure were observed were always fewer than 50 per cent and the percentage decreased greatly as more clockwise rotation was observed. When they saw only three exposures they failed to see any of the four though there was a slight tendency to skip the first exposures bordering the smallest angle. On the contrary a few subjects reported four or two exposures in the three-place pictures.

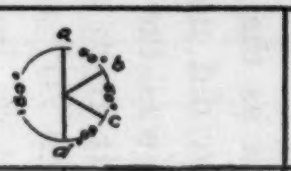
The conic motion was still seen though very few times and they were not positive as to which of the four places was out toward the subject or away from him. The circle of the cone was very large in all series. The voluntary effort to make the bar go around worked contrariwise in this experiment. The result was worse, making the bar flap over at the greatest distance. (See Table VI.)

Experiment XII
(17 Series)

Procedure: In this and the following experiments a diameter was exposed instead of a radius, successively from the perpendicular position to the right on its center point as a pivot.

Table VI

Size of bar: 11 cm. by 1 cm.
No. of subjects: 15

Exposure positions and distances between them										
Lengths of pause	1	1	1	1	1	1	1	1	1	2 betw. d & a	3 betw. d & a	4 betw. d & a	1	2 betw. d & a
Clockwise rotation	94	94	91	97	84	84	53	40	14	26	20	23	9	11
Clockwise rotation changed to flap over			3	3		6	9	17	9	3	9		3	9
Flap over big distances	6		6		13	3	32	34	74	66	50	48	80	66
Disapper or hide at. big distances								6	3	6	17	28	3	9
Conic rotation		6			3	6	6	3			3		6	6
Total no. of records	31	31	31	31	31	31	34	35	35	35	35	35	35	35

The degree of movement at each exposure was varied in each series. The pause of one section between successive pictures was kept constant.

Results: The clockwise rotation of the bar was reported in 71 per cent of cases in the 70° step picture, after which it suddenly decreased and only gradually died out as the step became larger, while the counter-clockwise rotation did not appear so decidedly in the 110° step picture which was the same thing as to have removed the bar 70° to the left from the previous position. In the pictures with steps between 70° and 110° the back and forth motion or flashing off and on impression was most prominent, reaching its height in the pictures with 87½° and 90° steps. The conic motion seems to have appeared along with the back and forth motion and showed no particular preference for the size of the steps, except in the 90° steps where no conic motion was observed. The back and forth motion mixed with the clockwise rotation was more frequently seen in the region where the simple clockwise rotation was more often seen, and the back and forth motion mixed with the counter-clockwise rotation was more frequently observed in the region where the simple counter-clockwise rotation prevailed. The mixed motions and jumble appeared in the transition or indefinite region more than in any other place. (See Table VII.)

The " mixed motions " mean the impressions of motion which alternated their form or direction more than twice during the exposure of the series. The " jumble " means an indescribable motion or motions mixed in such a disorderly way that the subject could not get any impression of the definite form.

Experiment XIII

(13 Series)

Procedure: All things were similar to the last experiment except that two diameters crossing at the right angle in the center were exposed simultaneously instead of one diameter at a time, and the whole thing was moved a certain degree at each exposure.

Results: The clockwise rotation was observed decidedly in the pictures with steps from 30° to 37½° and possibly in the 40° step picture. Then it suddenly dropped in the next picture

TABLE VII

Stimulus pattern: (See Fig. 7 on page 89).
Size of the bar: 22 cm. by 1 cm.
Length of the pause: One.

No. of subjects: 17
No. of records: 34.

Angle per step	70.0°	72.5°	75.0°	77.5°	80.0°	82.5°	85.0°	87.5°	90.0°	92.5°	95.0°	97.5°	100.0°	102.5°	105.0°	107.5°	110.0°
Clockwise rotation....	71	26	18	..	9	3	9	..	9	9	6	9	..	3	..	..	..
Back-forth changed to clockwise rotation...	3	6	9	9	..	6	15	..	3	..	3	..	..	3	3	3	..
Counter-clockwise rotation.....	3	..	..	..	..	3	3	..	6	6	..	3	9	9	3	12	24
Back-forth changed to counter-clockwise rotation.....	..	..	..	3	6	3	..	..	3	..	..	..	6	12	12	6	6
Back-forth motion....	15	24	32	53	38	21	44	76	79	59	59	41	41	41	26	41	38
Conic rotation.....	..	3	3	3	9	3	3	6	..	12	3	3	6	3	6	..	..
Back-forth changed to conic rotation.....	..	9	..	..	3	21	3	3	..	..	3	6	6	6	9	6	..
Back-forth and clockwise rotation.....	3	12	18	6	6	3	..	..	..	9	24	21	26	21	21	9	15
Back-forth and ccw. rotation	3	9	12	12	21	35	18	15	..	..	3	6	3	3	9	6	3
Mixed motions.....	..	3	3	9	6	3	6	..	..	3	..	6	3	..	12	18	12
Jumble.....	3	9	6	6	3	..	..	..	..	3	..	6	..	..	..	..	3

with the larger step but showed itself better again in the 45° step picture, after which it dropped to rise no more. The counter-clockwise rotation seemed to be coming at the 32½° step but it did not show itself purely and decidedly until the 55° step. The back and forth motion and the flashing off and on of the bars were reported only in pictures with the 45° step and then rather seldom. The mixed motions and the jumble were clustering in the neighborhood of the 45° step picture marking the most uncertain region from 42½° to 50° steps. (See Table VIII.)

Experiment XIV

(9 Series)

Procedure: The three diameters crossed at the center point equidistantly to each other were exposed simultaneously in the same way as before.

Results: The clockwise rotation in its pure form was observed in a large percentage of cases, even in the 27½° step picture, and not at all after the 30° step picture. The counter-clockwise rotation appeared at the 30° step and increased very rapidly at the 32½° step and was almost always present at the 35° step although some subjects saw clockwise rotation for a little while at the beginning or end of these series. The mixed motions and jumble appeared within 5° around the 30° step picture. (See the table on page 48.)

C. *Comparison of Apparent Speed:*

During the course of the previous experiments there were spontaneous remarks thrown in by various subjects, which aroused the curiosity of the experimenter in regard to the psychological nature of the speed of motion. Often times the report of faster motion was given when it was really slower physically. That is, the pictures were being shown with longer pauses. This came when no request had been given to make a comparison. These casual remarks were too frequent to ignore and led the experimenter to plan some series of experiments for comparison of speed alone in the apparent movement. In order to produce different speeds one or two of the following factors were varied in various combinations, the length of pause, the distance covered

TABLE VIII

Stimulus pattern: (See Fig. 8 on page 89).
Size of the bar: 22 cm. by 1 cm.
Length of the pause: One.

No. of subjects: 17.
No. of records: 34.

Angle per step	30.0°	32.5°	35.0°	37.5°	40.0°	42.5°	45.0°	47.5°	50.0°	52.5°	55.0°	57.5°	60.0°
Clockwise rotation	100	97	97	97	76	24	41	6	3	3	..	3	..
Counter-clockwise changed to clockwise rotation	..	3	3	3	..	9	3	6	9	3	..	..	..
Counter-clockwise rotation	..	..	..	..	..	3	18	15	32	76	100	91	100
Clockwise rotation changed to counter-clockwise rotation	..	..	..	..	21	35	9	53	50	15	..	6	..
Back-forth or flashing on and off	..	..	..	..	..	..	9	..	..	..	..	..	..
Mixed motions	..	..	..	..	..	21	12	12	6	3	..	..	..
Jumble	..	..	..	..	3	9	9	9	..	..	..	..	..

by the bar in a given time (exposure time plus pause), and the frequency of the exposure of the bar within the same distance. Two forms of motion were used, rotation of a radius and back and forth motion when the lines were at an angle.

TABLE IX

Stimulus pattern: (See Fig. 9 on page 89).
Size of the bar: 22 cm. by 1 cm.
Length of the pause: One.
No. of subjects: 17.
No. of records: 34.

Angle per step	20°	22½°	25°	27½°	30°	32½°	35°	37½°	40°
Clockwise rotation.....	100	94	100	59	24	..	..	..	..
Counter-clockwise rotation changed to clockwise rotation.....	..	..	..	12	15	6	6	..	..
Clockwise rotation changed to counter - clockwise rotation.....	..	..	..	6	6	18	32	12	..
Counter-clockwise rotation	..	6	..	..	9	41	59	88	100
Flash off-on changed to counter-clockwise rotation.....	..	..	..	..	..	..	3	..	..
Flash off-on.....	..	..	..	15	24	9	..	..	..
Mixed motions.....	..	..	..	6	12	18	..	..	..
Jumble.....	..	..	..	3	12	9	..	..	..

All through these series the comparison was made by pairs, each member of the pair being shown for about two seconds with one second blank period between members to mark the end of the first and the beginning of the second member. At the end of each pair introspections were recorded. Each pair was repeated in the right and reversed orders in all series. The right order meant that the first member of the pair was faster than the second; the faster picture meant that either the bar took less time to cover the same distance or it covered a greater distance in the same length of time.

The special instruction given was: "Two series of pictures are going to be shown one after the other. A short blank period will mark the end of the first series and the beginning of the second. I want you to watch the speed of the motion in the two pictures and tell me which seems to be moving faster, the first pic-

ture is running faster than the second, or the second faster than the first, or else both seem alike in speed. I may ask something else but the speed is of the first importance in this experiment, so you must get speed first and then if you have time watch other things too. Do not count numbers or make movements with any part of your body. It will not help you. Just watch calmly and easily with all attention on the screen because they are shown a very short time and it may be very difficult to make any judgment on them unless you watch carefully."

Experiment XV

(4 Series)

Procedure: A bar was exposed in two different places alternately and repeatedly with the left end at a common point so that two successive exposures made an angle opening to the right above the horizontal bar. The pause was one section always, and the distance was varied between 60° and 40° by 5° steps. Pairs were made by all possible combinations.

Results: The speed of the second member in the pair was judged as faster very frequently and showed a tendency in general to acceleration. There was no correspondence between the kind of judgment and the amount of difference in the speeds compared. Whether the difference was 5° or 20° the number of times a certain judgment was given did not differ much. The total number of the judgment "same" was very much greater in the right order than in the reversed order. Similarly the judgment "the second is faster" was greater in the reversed order. These two facts suggest some influence of the distance upon the judgment of speed although all introspections did not confirm it. Some subjects gave the greater distance as the cause of the faster speed, but it was not constant either in the same or different individuals. Some others said, when asked about it after the series of pictures, that the size of the angle did not make any difference in the speed of motion of this kind. For instance, they judged the speed by how frequently the bar came to the top position in the same length of time. If it came oftener it was judged as faster. (See Table X.)

TABLE X

Stimulus pattern: (See Fig. 1 on page 89).
Size of the bar: 22 cm. by 1 cm.
Length of the pause: One.
No. of subjects: 15.
No. of records: 30.

Pair compared in terms of distance between exposure places	Difference between 1st and 2nd members	Right Order (1st member has greater distance)			Reversed Order (2nd member has greater distance)			Totals of wrong judgments
		Number of judgments			Number of judgments			
		1st fast (right)	Both same	2nd fast	1st fast	Both same	2nd fast (right)	
60° : 55°...	5°	7	27	67	3	17	80	55
60° : 50°...	10°	7	53	40	..	3	97	48
60° : 45°...	15°	13	27	60	10	7	83	52
60° : 40°...	20°	7	30	63	..	13	87	53
Totals.....		8	34	58	3	10	87	53

Experiment XVI

(6 Series)

Procedure: A radius was moved a certain distance in clockwise direction at each successive exposure. Different degrees of movement were used in different series with the constant pause of one section after each exposure; other conditions were similar to those of Experiment XV.

Results: The speed of the second member in the pair was judged as faster in many cases. As the difference of speed in the pair became greater the number of right judgments was correspondingly increased in both orders. We assume the judgment was right when the motion was judged as faster in the picture which had gone a longer distance between successive exposures in the same period of time than in the picture which had a shorter distance. In this experiment the distance was indicated by the size of the steps at each exposure. See Table XI for the details.

TABLE XI

Stimulus pattern: (See Fig. 6 on page 89).
Size of bar: 11 cm. by 1 cm.
Length of pause: One.
No. of subjects: 15.
No. of records: 30.

Pair compared in terms of size of steps at each exposure	Difference between 1st and 2nd members	Right Order (1st member has larger steps)			Reversed Order (2nd member has larger steps)			Totals, of wrong judgments
		Number of judgments			Number of judgments			
		1st fast (right)	Both same	2nd fast	1st fast	Both same	2nd fast (right)	
55° : 52½°..	2½°	3	43	53	0	23	77	60
55° : 50°....	5°	10	40	50	3	7	90	50
55° : 47½°..	7½°	13	67	20	0	13	87	50
55° : 45°....	10°	23	57	20	0	17	83	47
55° : 42½°..	12½°	40	47	13	3	0	97	32
55° : 40°..	15°	50	47	3	0	3	97	27
Totals.....		23	50	27	1	11	88	45

EXPERIMENT XVII

(15 Series)

Procedure: A bar was exposed in the same manner as in Experiment XV, the angular distance being always 45° and the pause varied from one to seven in different series.

Results: The speed of the second member in the pair was judged as faster in many cases. It was especially so in the reversed order where the second member had a shorter time interval than the first member. In all the pairs of the reversed order, in which the difference of the two speeds was two sections of the film (120 σ), the right judgments were given in more than 90 per cent of cases, and when the difference was decreased to one section (60 σ), the percentages of the right judgments remained above 80 per cent, while in the pairs of the right order the same differences of the speeds did not give such uniform

results. The judgments given in the right order showed, on the other hand, a very close correspondence to the amount of difference of the two speeds compared. That is, the greater the difference in the two speeds compared, the greater the number

TABLE XII

Stimulus pattern: (See Fig. 1 on page 89).
Size of the bar: 22 cm. by 1 cm.
Length of the pause: 1 to 7.
Distance: 45°.
No. of subjects: 15.
No. of records: 42.

Pair compared in terms of whole time taken in one way	Difference between 1st and 2nd members	Right Order (1st member has shorter pause)			Reversed Order (2nd member has shorter pause)			Totals of wrong judgments
		Number of judgments			Number of judgments			
		1st fast (right)	Both same	2nd fast	1st fast	Both same	2nd fast (right)	
2 : 3	1	76	5	19	..	5	95	14
3 : 4	1	60	19	21	5	7	88	26
4 : 5	1	48	38	14	..	5	95	28
5 : 6	1	10	71	19	..	12	88	51
6 : 7	1	12	69	19	..	10	90	49
7 : 8	1	21	60	19	..	19	81	49
2 : 4	2	86	7	7	..	2	98	8
3 : 5	2	76	12	12	..	2	98	13
4 : 6	2	80	10	10	..	..	100	10
5 : 7	2	57	38	5	..	2	98	23
6 : 8	2	71	24	5	..	7	93	18
3 : 6	3	88	7	5	..	..	100	6
4 : 7	3	93	5	2	..	7	93	7
5 : 8	3	93	5	2	..	2	98	5
4 : 8	4	100	..	..	..	..	100	0
Totals.....		64	25	11	0	5	95	21

of the right judgments. However, the ratio of the two speeds did not show such a good correspondence to the correctness of judgment. In the pairs where the difference between the two speeds was the same, with a few exceptions, more wrong judgments appeared in the slower motions, that is, in the pictures with longer pauses. These exceptions may not be so significant as the cases did not deviate from the average very much in each group. See Table XII.

TABLE XIII

Stimulus pattern: (See Fig. 6 on page 89).
Size of bar: 11 cm. by 1 cm.
Pause: 1 to 7.
Distance: 45° per step.
No. of subjects: 12.
No. of records: 24.

Pair compared in terms of whole time per step	Ratio of two speeds in the pair	Right Order (1st member has shorter pause)			Reversed Order (2nd member has shorter pause)			Totals of wrong judgments
		Number of judgments			Number of judgments			
		1st fast (right)	Both same	2nd fast	1st fast	Both same	2nd fast (right)	
2 : 4	1 : 2	79	13	8	..	..	100	10
3 : 5	3 : 5	58	17	25	..	13	87	27
2 : 3	2 : 3	75	17	8	..	4	96	15
4 : 6	2 : 3	42	29	29	..	8	92	33
5 : 7	5 : 7	45	38	17	4	..	96	29
3 : 4	3 : 4	29	42	29	4	8	88	42
6 : 8	3 : 4	87	13	..	4	29	67	23
4 : 5	4 : 5	37	42	21	4	8	88	38
5 : 6	5 : 6	49	38	13	8	33	59	46
6 : 7	6 : 7	25	58	17	4	13	83	46
7 : 8	7 : 8	20	63	17	4	13	83	48
Totals.....		50	33	17	3	12	85	33

Experiment XVIII

(11 Series)

Procedure: A radius was removed 45° in the clockwise direction at each successive exposure with a pause of different lengths in different series.

Results: As a whole tendencies in the results were similar to those in the results of the last experiment. The main differences were that a somewhat smaller number of right judgments was given and that the ratio of the two speeds compared showed a better correspondence with the correctness of judgments. That is to say that the greater the ratio of the two speeds compared, the larger the number of the wrong judgments, while the difference of the two speeds did not show as good a correspondence as this. A greater number of wrong judgments was given in the slower pictures. See Table XIII.

Experiment XIX

(5 Series)

Procedure: In this experiment the variable factor was the number of exposures of the bar within the same angular distance. The unit of the distance was 45° and the bar was exposed once, twice, or three times within that unit distance. The pause was adjusted to be longer or shorter so that the whole time (exposure time plus pause) taken to go the unit distance was the same in both members of the pair. That is to say that the bar went 45° in one step, two steps, or three steps, the size of the steps being 45°, 22½°, and 15° respectively and the pause was shortened accordingly as more time was taken for exposures. The Table XIV will show these details. The back and forth motion form was used in the angular arrangement.

Results: From the objective conditions and our assumption that the motion can be considered as of the same speed when the distance and the time taken to go that distance were identical, disregarding the different lengths of pause and different numbers of exposure, we expect the judgment " The speed of both members is the same " to be correct in this and the next experiments.

The number of the right judgments in both orders was much less in this experiment than in the previous ones. Consequently a great increase of the wrong judgments was noticed. In the pair where both members differed extremely in the size of the steps and pauses, the pictures with larger steps and longer pauses in both orders gave the faster impression than the pictures with smaller steps and shorter pauses. See the row headed with $I^5 : III^1$ in Table XIV. The judgment "Both same" was given very frequently when both members did not differ very widely in the size of the steps and pauses. Differences in the length of pauses and size of steps complicated the matter, along with the acceleration tendency of the second speed. Any further analysis of the results is impossible here. See Table XIV.

TABLE XIV

Stimulus pattern: (See Figs. 1, 2, 3, on page 89).
Size of the bar: 22 cm. by 1 cm.
Length of the pause: 1 to 5.
Size of the steps: 45.0°, 22.5°, 15.0°.
No. of subjects: 15.
No. of records: 30.

Pair compared in terms of number of steps and length of pause	Pair in terms of whole time	Right Order (1st member takes larger steps)			Reversed Order (2nd member takes larger steps)			Totals of wrong judgments
		Number of judgments			Number of judgments			
		1st fast	Both same (right)	2nd fast	1st fast	Both same (right)	2nd fast	
$I^3 : II^1$	4 : 4	33	13	53	10	3	87	92
$I^5 : II^2$	6 : 6	17	23	60	7	20	73	78
$I^5 : III^1$	6 : 6	50	20	30	13	10	77	85
$II^2 : III^1$	6 : 6	37	40	23	3	33	63	63
$II^5 : III^3$	12 : 12	3	33	63	27	30	43	68
Totals.....		28	26	46	12	20	68	77

* The Roman figures indicate the number of steps and the Arabic figures on their upper right corner indicate lengths of pause. These apply for all other similar tables.

Experiment XX

(5 Series)

Procedure: The same as in Experiment XIX except that the form of the motion was rotation of a radius.

Results: A few more right judgments were given here than in the last experiment although it was still far less than in the other experiments. In the pair where both members differed extremely in size of steps and pauses, the picture with the larger steps and longer pauses was judged as faster in both orders. Small steps with shorter pauses on the whole gave the faster impression more frqeuently in this than in the last experiment. See Table XV.

TABLE XV

Stimulus pattern: (See Fig. 6 on page 89).
Size of the bar: 11 cm. by 1 cm.
Length of the pause: 1 to 5.
Size of the steps: 45°, 22½°, 15°.
No. of subjects: 12.
No. of records: 24.

Pair compared in terms of number of steps and length of pause	Pair in terms of whole time	Right Order (1st member takes larger steps)			Reversed Order (2nd member takes larger steps)			Totals of wrong judgments
		Number of judgments			Number of judgments			
		1st fast	Both same (right)	2nd fast	1st fast	Both same (right)	2nd fast	
I^3 : II^1	4 : 4	25	29	46	33	29	38	71
I^5 : II^2	6 : 6	8	4	88	21	38	42	79
I^5 : III^1	6 : 6	46	33	21	17	25	58	71
II^2 : III^1	6 : 6	21	29	50	4	50	46	60
II^5 : III^3	12 : 12	25	17	58	33	39	29	72
Totals.....		25	22	53	22	36	42	71

Experiment XXI

(17 Series)

Procedure: The length of pause and the number of exposure positions of the bar within the unit distance, 45°, were both

varied and all combinations were made into pairs. Details are found in Table XVI.

TABLE XVI

Stimulus pattern: (See Figs. 1, 2, 3 on page 89).
Size of the bar: 22 cm. by 1 cm.
Length of the pause: 1 to 5.
Size of the steps: 45.0°, 22.5°, 15.0°.
No. of subjects: 15.
No. of records: 30.

Pair compared in terms of number of steps and length of pause	Pair in terms of whole time	Ratio of speed in terms of time	Right Order (1st member takes less time)			Reversed Order (2nd member takes less time)			Totals of wrong judgments
			Number of judgments			Number of judgments			
			1st fast (right)	Both same	2nd fast	1st fast	Both same	2nd fast (right)	
I^1 : II^1	2 : 4	1 : 2	87	13	..	..	..	100	7
I^2 : II^2	3 : 6	1 : 2	87	3	10	..	..	100	7
I^2 : III^1	3 : 6	1 : 2	93	..	7	..	..	100	3
I^3 : II^2	4 : 6	2 : 3	56	27	17	3	..	97	23
I^3 : III^1	4 : 6	2 : 3	80	10	10	3	..	97	12
II^1 : III^1	4 : 6	2 : 3	67	20	13	3	..	97	18
I^5 : III^2	6 : 9	2 : 3	63	20	17	3	10	87	25
II^2 : III^2	6 : 9	2 : 3	40	27	33	..	7	93	32
II^3 : III^3	8 : 12	2 : 3	47	20	33	..	3	97	28
II^4 : III^4	10 : 15	2 : 3	30	40	30	..	3	97	37
I^2 : II^1	3 : 4	3 : 4	50	33	17	..	3	97	27
I^5 : II^3	6 : 8	3 : 4	50	20	30	..	3	97	27
II^5 : III^4	12 : 15	4 : 5	14	33	53	7	40	53	67
I^4 : II^2	5 : 6	5 : 6	37	23	40	3	3	94	35
I^4 : III^1	5 : 6	5 : 6	67	20	13	..	7	93	20
II^4 : III^3	10 : 12	5 : 6	20	30	50	20	50	30	75
II^3 : III^2	8 : 9	8 : 9	14	43	43	7	23	70	58
Totals.....			53	22	25	3	9	88	30

Results: The absolute difference of the two speeds did not show any corresponding variation in the results, while the ratio of the two speeds showed a better correspondence with the correctness of the judgments, the larger the ratio, the easier to judge correctly. The ratio 1:2 in terms of time taken to go the distance of 45° gave more than 87 per cent of right judgments despite the tendency to accelerate the speed of the second member. The pairs with other ratios showed more variations in the number of different judgments owing to other factors than the time relation. Among the series which had the same ratio the right judgment was more frequent when the size of the steps and the length of pauses were very different in both members or very similar. When members were slow with long pauses and many steps the wrong judgments were very frequent despite other favorable conditions.

Experiment XXII

(14 Series)

Procedure: The same procedure as in Experiment XXI was used with the rotary motion of a radius.

Results: Results were in every respect very similar to those in the last experiment. A slight increase in the total number of the wrong judgments may be due to the fact that we did not include those three pairs with the ratio 1:2 in this experiment. See Table XVII.

Experiment XXIII

(14 Series)

Procedure: Before going into a discussion of the phenomena we need to bring in the most conspicuous points of the different impressions produced by the variable factors on the appearances of the entire picture. Very frequently subjects complained of the impossibility of comparison of two such different things. These complaints were expected by the experimenter but the complicated interaction of the factors necessitated a special study of some phases of the complaints. Showing the same pictures that we used for the speed comparison in pairs or singly, other

things than speed were studied in a manner similar to that used in the other experiments.

Results: In the angle arrangement the size of the distance was not being observed correctly. The more complicated the picture was, the less correct the estimate. In the simple pictures used in

TABLE XVII

Stimulus patterns: (See Fig. 6 on page 89).
Size of bar: 11 cm. by 1 cm.
Length of pause: 1 to 5.
Size of steps: 45°, 22½°, 15°.
No. of subjects: 12.
No. of records: 24.

Pair compared in terms of number of steps and length of pause	Pair in terms of whole time	Ratio of speed in terms of time	Right Order (1st member takes less time)			Reversed Order (2nd member takes less time)			Totals of wrong judgments
			Number of judgments			Number of judgments			
			1st fast (right)	Both same	2nd fast	1st fast	Both same	2nd fast (right)	
I^3 : II^2	4 : 6	2 : 3	79	8	13	4	..	96	13
I^3 : III^1	4 : 6	2 : 3	74	13	13	..	13	87	19
II^1 : III^1	4 : 6	2 : 3	37	42	21	4	13	83	35
I^5 : III^2	6 : 9	2 : 3	74	13	13	..	4	96	15
II^2 : III^2	6 : 9	2 : 3	79	21	..	4	8	88	17
II^3 : III^3	8 : 12	2 : 3	74	13	13	..	..	100	13
II^4 : III^4	10 : 15	2 : 3	29	25	46	4	29	67	52
I^2 : II^1	3 : 4	3 : 4	50	17	33	..	4	96	27
I^5 : II^3	6 : 8	3 : 4	46	21	33	17	17	66	44
II^5 : III^4	12 : 15	4 : 5	33	13	54	8	42	50	58
I^4 : II^2	5 : 6	5 : 6	37	21	42	8	29	63	50
I^4 : III^1	5 : 6	5 : 6	74	8	17	8	17	75	25
II^4 : III^3	10 : 12	5 : 6	50	25	25	17	50	33	58
II^3 : III^2	8 : 9	8 : 9	41	21	38	4	29	67	46
Totals.....			56	18	26	6	18	76	34

Experiment XV with pauses and number of exposure places constant and distances varied, over-estimation and under-estimation were both present for the same picture but the average showed an over-estimation. The estimates made by comparing two pictures and that by observing single pictures were very different, the former having shown now a marked over-estimation, again a marked under-estimation, and the latter fairly uniform over-estimation, which was about 6° for every angle we used. In the pictures used in Experiment XXI, where the pause and the number of exposure places were varied, the estimation of the angle was in both directions, over and under. Pictures which had either long steps or long pauses were over-estimated invariably and those which had short steps and short pauses were under-estimated, either of which alone was not able to induce under-estimation. Thus the largest step 45° and the pauses 4 and 5 were all found in the over-estimated pictures and the rest in the under-estimated ones. The maximum of over-estimation was 7° and that of under-estimation was 12° on the average. In this estimation of the distance the time factor showed a very strange relation. That is, the over-estimated pictures contained both pictures which took shortest and longest times to go the same distance and the under-estimated pictures took the medium times.

The types of the motion produced by the successive exposures of the bar in an angular arrangement were discussed in the earlier experiments. We need only to add some new phenomena found in this particular arrangement of the stimulus pattern. We found a great increase of the third dimensional conic motion, especially in the pictures with smaller steps, 22½° and 15°, where the size of the pause did not seem to affect it at all, while in the pictures with the largest step the longer pauses seemed to favor the conic motion. Flashing impression was reported very seldom and very irregularly. The self-rotation in combination with other motions was reported rather often. The most frequent appearance of it was in the pictures with short steps and short pauses, II^1, II^2, III^1, III^2, the former showing a stronger influence over against the latter. That is, there was much more self-rotation reported in the small step pictures with long pauses than in large step

pictures with short pauses. The fact should be mentioned that showing two series of pictures in succession for observation, not for a comparison specially, produced a great increase in the conic motion and self-rotation while a single series shown by itself for the same purpose reported much less conic motion and self-rotation.

Along with the motion of the bar various remarks about the appearance of the bar were mentioned as in the other experiments. The special remark in this group of experiments was that the bar seemed not quite straight during the motion although it was straight in the extreme positions at top and bottom. Ten out of fifteen subjects saw the bending effect of the bar during the observation of the speed. Four out of these ten subjects did not see it when special attention was called to it, while another four saw it very often whether attended to or not, and the rest saw it rather occasionally. The pictures that produced the bending effect most frequently were III^1, II^2, and II^1 in the order of frequency. Others showed it very seldom. The shape of the bending was approximately as follows:

Now the films were cut into halves and quarters to reduce repetitions and see how it affected the bending. Fewer repetitions of exposure affected the bending appearance almost fatally. Only a very slight tendency to bending was reported once each in the pictures II^1 and II^2, whose length of film was one-half of the original, and none was seen in the pictures of one-quarter length. However, we tried only two of the original subjects for this last part of the observation, as we were not able to find good subjects from the new ones. See Table XVIII.

In connection with the bending appearance of the moving bar let us mention another instance of bending, which was reported in Experiment XIII. When the two crossed diameters were being

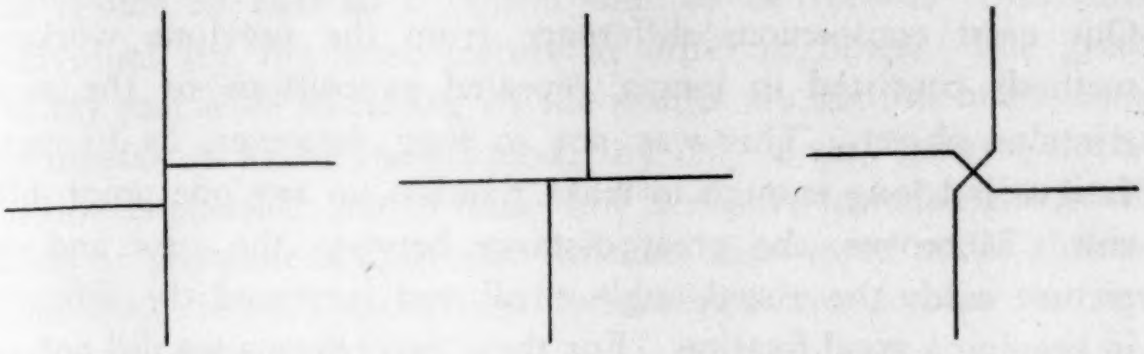
TABLE XVIII

Stimulus pattern: (See Figs. 1, 2, 3, on page 89).
Size of the bar: 22 cm. by 1 cm.
Length of the pause: One.

Size of the steps: 45.0,° 22.5°, 15.0°.
No. of subjects: 15.
No. of records: Not uniform.

Number of steps and length of pauses	I¹	I²	I³	I⁴	I⁵	II¹	II²	II³	II⁴	II⁵	III¹	III²	III³	III⁴
Back-forth motion	89	77	72	75	74	55	53	55	63	67	56	54	56	53
Conic motion	11	21	26	22	22	44	44	45	35	33	42	46	43	47
Flashing off and on	..	2	2	3	4	1	3	0	2	0	3	0	1	0
Self-rotation	6	8	3	3	3	30	37	25	17	19	48	43	18	22
	Visual Estimation of the Unit Distance 45° Averaged													
Estimated Distance in degrees	*52°−*	*45°+*	*48°+*	*50°+*	*52°−*	*33°−*	*38°−*	*42°+*	*48°+*	*48°−*	*33°−*	*39°+*	*40°−*	*49°−*
	Bending Effect Observed by 10 Subjects out of 15													
No. of subjects	*2*	*2*	*2*	*1*	*1*	*4*	*7*	*1*	*3*	*1*	*9*	*2*	*1*	*3*
No. of cases	*4*	*3*	*2*	*1*	*1*	*19*	*24*	*3*	*3*	*1*	*60*	*6*	*2*	*3*

repeatedly shown the subject reported that they were not quite straight but somehow bent near the crossing point. The ends and center of the diameters seemed as if not moving at the same speed or not meeting exactly in one point as two straight bars should and yet they were not four short bars. No subject was able to describe exactly how they bent but agreed approximately with the following patterns:



Some subjects felt that the eye-movement together with the bars would prevent bending and so they kept the eyes stationary. They also felt that the bars were clear and dark when no bending was seen. Another subject said that when she looked at the whole thing "harder" the bars became straight and the bending appeared when she was not looking "so hard" and when she was looking at each bar separately. This bending was present only in the pictures which showed the definite direction of rotation either clockwise or counter-clockwise and never in the indefinite pictures. It is also to be noted that this was absent in the pictures of one diameter or three diameter arrangements. Fewer repetitions of exposures did not favor the bending effect. All subjects complained of its being too short and of being unable to get any ideas about the appearance of the pictures when the film was short.

DISCUSSION

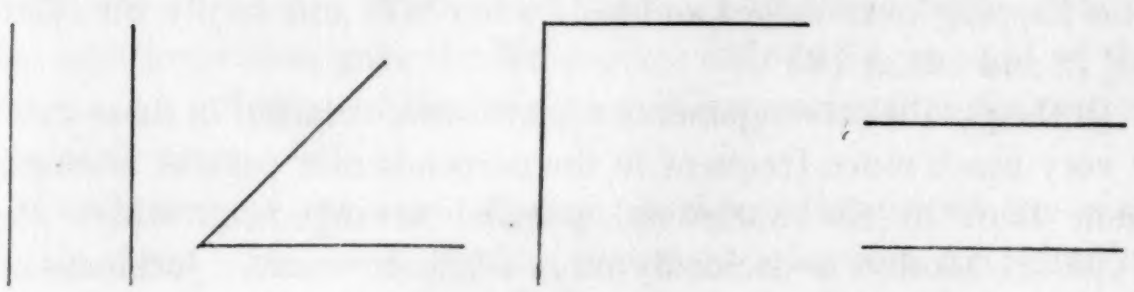
Since our particular method of experimenting is different from those used before, our findings might be expected to throw some new light upon the problem of apparent movement. Our most conspicuous difference from the previous workers' methods consisted in longer repeated expositions of the same stimulus object. This was not so long, however, as to cause fatigue but long enough to make fixation on any one point difficult. Moreover, the great distance between the eyes and the picture made the visual angle small and increased the difficulty in keeping a good fixation. For these two reasons we did not use any fixation point during the observation. In this non-fixated observation we should expect free movement of the eyes. The eyes may or may not go together with attention, which is guided by the instruction at the beginning of the observation and later by the meaning of the object seen. When the instruction given was just to watch and tell whatever was shown on the screen, the quick appearance and disappearance of the black bar on the white background catches the subject's eyes and attention first, but soon he is busy evaluating all the sensations in reference to time and space in order to get a definite relationship between them, which will make the object take on a certain movement of the thing seen. When the meaning is obtained, his attention is directed to it and he endeavors to obtain details of the appearance of the thing seen. According to the subject's report his eyes are not always on the moving object to which he is attending. In most cases, it is moving too quickly for the eyes to follow. He fixates his eyes more or less on one part of the picture for some moments. Then attention goes all over the field to get all possible information, and this is the best way to get a clear idea of the whole thing. Moving the eyes too much with the object does not help to get a clear perception. However, there is a momentary

fixation which shifts from time to time, from place to place, within the visual field, seeking the most suitable places of fixation for the clearest perception of various phases of the object. Then it is evident that an innumerable variety of impressions is likely to result from free non-fixated observations.

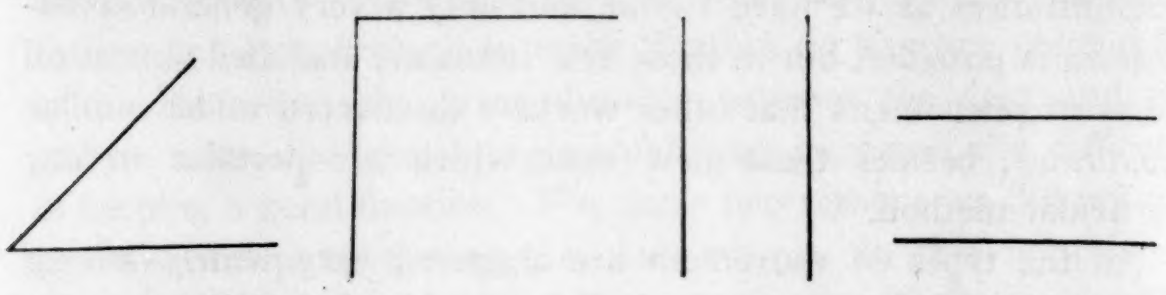
The greater number of the subjects we used in the experiments bring in greater individual differences and give more variety in the results as well as a greater number of records from each individual for the same picture at different times. The great variety and wide scattering of the results are natural under such circumstances as we have found, and only a very general classification is possible; but in those few items are included almost all kinds of phenomena that other workers discovered under similar conditions, besides those new ones which are peculiar to our particular method.

All the types of movement are scattered very widely among different pauses but percentages of frequency suggest the presence of relationship between types of movement and lengths of pause. The Type I Motion which is the real continuous motion back and forth between the two places of exposure, is dominant in the pictures where the pause is 70 σ or 130 σ, namely, in P.1 and P.2 Series respectively, and in all stimulus arrangements excepting the horizontal parallel arrangement, where it drops below 50 per cent in the P.2 Series. The Type III Motion or really the mere succession is sure in the P.5 Series where the pause is 130 σ and probably in the P.4 Series. This leaves the partial movement in a rather narrow limit. The P.3 and P.4 Series have almost every type of motion.

As to the relationship between Type I Motion and the stimulus patterns, the order of frequency from the highest to the lowest is:



The Type I Motion does not always mean the flat back and forth motion on the plane but it includes also the motion in the form of a cone or drawing an arc in the air. These two forms of the back and forth motion may have another motion simultaneously, which is the revolving appearance of the bar on its own axis. This is designated as " self-rotation " in the tables, and will be discussed later. The three dimensional cylindrical rotation is very frequently seen in the parallel arrangements, and so if we arrange in the order of the flat back and forth motion alone, the order of frequency is altered as follows:



This indicates that the smaller angle is better for the production of the movement and the angular arrangements are better than the parallel ones.

In the arrangement of 90°, when compared with that of 45°, the Type III Motion is reported even in the P.1 Series, and as a whole it is more frequent; the movement is reported as jerky much oftener; the amount of partial movement covers a smaller fraction of the entire distance; illusion of speed of the motion tends to appear although it was not our intention to investigate it; the single part motion is more definitely and more frequently noticed. All these differences among the results in the angle arrangements seem to depend upon the greater distance between the two stimuli which in turn affects attention and the fixation point. If we use still larger angles the form of motion changes into flapping over rather suddenly after 90° and finally into sliding in and out at 180°.

In the parallel arrangements the cylindric rotation in these cases is very much more frequent in the perpendicular parallel arrangement than in the horizontal parallel arrangement where the Type III Motion is decidedly more likely to occur. Jerkiness of the motion is rare in the series with longer pauses in the perpen-

dicular parallel arrangement, while contraction and expansion of the bar (Gamma movement according to Kenkel (32) is equally frequent in both arrangements in all except the P.1 Series.

These differences between the effect of angular arrangements and the effect of parallel positions suggest that the impressions obtained from the two successive stimuli with similar temporal conditions are not similar when the relative positions of exposure of two stimuli are different. We may ask why the flat back and forth motion is seen more in the angular arrangement than in the parallel arrangements; why more cylindrical rotation is seen in the perpendicular parallel arrangement and more "flashing off and on" in the horizontal parallel arrangement; why "flapping over" is seen in the obtuse angular arrangement instead of the flat motion? The empiricist will say that it is far more natural to see the motions as they would occur in the real events in life. The opening-closing motion of doors, books, mouths, and the falling of standing sticks, umbrellas, trees are commonly experienced but the motion of the entire bar exactly sidewise or up-down is very uncommon. We are more likely to see the rotation of a pole or a part of an engine in the perpendicular position. In the horizontal case it is still more rare for a bar to fall down keeping the exact horizontal alignment and so if the time condition is a little unfavorable a motion of any kind is lost and the bar flashes off and on. The "flapping over" is the best possible interpretation of such a stimulus pattern as the obtuse angular arrangement.

The optimal motion form is still further aided by exposing a third or fourth line in the large angles and we see that the additional lines on one side helped to make the movement over the large angle on the flat surface. Almost all were on the surface when the angle was as small as 150°. This large angle without the additional lines gave the flat motion only in 13 per cent of the cases. An influence of the neighboring impressions on the motion is clearly seen.

Conditions of the conic motion in three dimensions are now fairly clear. The conic motion is present wherever the stimulus arrangement resembles a fan or cones. A little suggestion is

enough to arouse the perception provided the pause is not too short in proportion to the distance. If the positions of exposure are more evenly distributed around the center in the radial arrangement, the conic motion is hindered, but if they are on one side leaving a space of 190° on the other side, then the conic motion is perceived. It is more readily obtained when the pause is longer than one ($70\,\sigma$) in the 45° angle arrangement and very much better when the bar is exposed in small steps within the same angular distance. Then the length of pause does not matter. Behavior of this perception is similar to that of the stair-case illusion and others of like nature in being beyond the voluntary control.

When the bar is presented with the optimal pause, namely, one section of the film, in such positions that the whole picture is more or less symmetrical or when the bar is presented in each succeeding section in any pattern like Experiments VI and VII, we find that subjects find it difficult to give an accurate account of what is seen. They see some motion or " jumble " or just a " flash off and on ", all of which have no direction whatever, nor distance, though the bar is recognized. They seem to struggle even to get some idea from the whole thing and most of the reports are the results of their effort. If the picture shows any one-sidedness, that draws attention and movement of some sort is perceived on the side attended to, but the unattended side is not seen or is reported as mere " flashing off and on ". Experiments VII and VIII provide good examples. The many forms of movement in Experiment VIII take the " sliding in and out " type along with the successive positions of the bar, which is not the same kind of movement as in our other relations. Movement impressions in Experiments VI and VII, on the other hand, are various and often unreasonable or incompatible with other impressions. The bar is continuously and simultaneously seen in two positions in Experiment VI and yet is moving back and forth. This movement toward each other's position is not really seen, for it is too quick according to the subject's reports. We suspect that this direction of movement is centrally supplied from the relative positions of exposure and there might be left just moving impres-

sions when only one position is exposed in the similar temporal condition. In Experiment VII it is hard to estimate the direction since three different places are shown and those three positions are too far apart in space (120°) and too close together in time (merely the minimum 10 σ pause), so that even "sliding in and out" or "flapping over" is impossible and just "moving somehow" is the report.

These instances force us to think that there is "movingness" which has no direction and no speed. It is an instantaneous sensation, a sort of flashing, having no color and no meaning. The direction, speed, and color belong to the object and come from the meaning of the entire situation. The meaning comes from the object seen in relation to time, distance, intensity, shape, order of appearance, colors, relative positions of exposure, background, and subjective conditions, all of which are evaluated in relation to each other in the light of the past experiences of the individual. In other words, it is a perception in the ordinary sense, and ordinarily we do not think of the "movingness" and the meaning separately.

The self-rotation of the bar is a new form of movement phenomenon markedly revealed in this work. It must be due in part to the repeated expositions because not much has been said of this in the earlier papers. This phenomenon is not reported much in the pictures where there are longer pauses than two blank sections of the film between successive exposures. It is most frequently seen in the pictures with one or two additional lines exposed within the 45° angle with the pauses one or two, namely, II^1, II^2, III^1, and III^2 pictures in Table XVIII. It is equally well observed in all the pictures where no blank section of the film is put after each exposure, excepting the pictures with the shortest and the longest distances, namely, 10° and 90° in Experiment VI. In these latter pictures slightly smaller percentages of this phenomenon are obtained. Attention to the fact may help the phenomenon. Fewer individual differences are seen. It is to be noted that this phenomenon is not reported often in the pictures where pauses are short and no additional lines are exposed in the intermediate space so that the two lines are 45° apart. This is

the case in the I^1 and I^2 pictures in Table XVIII, but is not seen in other pictures of the radial and diametric arrangements which are moving in one direction.. All this shows that the small distance and short pause between successive exposures and a little greater distance with still shorter pause ($10\,\sigma$) are the conditions in addition to repeated expositions which favor it. The spatially successive expositions of the bar as in the pictures of two steps and three steps in Table XVIII are important to the phenomenon because the outside bars in these pictures would not show so much rotation under the similar temporal condition without the middle bars.

Equally peculiar to this experimental method is the bending effect of the moving bar. This is also favored by short pauses and small successive steps in the angular arrangement, but the pause shorter than $70\,\sigma$ does not seem to be a substitute for a larger distance. Numerous repeated exposures are very necessary; attention to it hinders the phenomenon; great individual differences are noticed. It is not present in any other pictures than the pictures of two steps and three steps and the crossed diameters.

Besides these particular phenomena the effect of repeated expositions is seen in many other places throughout this work. Frequently we had instances where one kind of motion was seen at the start of the series and it changed into another kind later in the series. For instance, a radius seemed to be flapping over the largest angle in the four-place picture in the beginning but soon it went around on the plane or *vice versa,* or sometimes this alteration of the form of motion took place more than once during one continuous series of pictures. Looking over similar instances we have come to the conclusion that the effect of the repeated expositions is similar to the summation effect, bringing out the peculiarities of each series more clearly and strongly. The repeated observations do not help to see the movement under the unfavorable conditions as predisposition does, although they bring out a weak tendency if there is any. When two tendencies of slightly different strengths coexist in the same impres-

sion, the stronger one will stand out much more decidedly after repeated observations.

The impression of jerkiness in the movement is present either with long pauses or long distances. It seems to be the feeling present when the proper proportion between time and space is lost so that the temporal or spatial gap is too large and breaks the smooth continuity of the movement. Almost all apparent movement is jerky compared with the real movement of a disk, for instance.

Just a few words are enough for the contracting and expanding phenomena of the bar as it disappears and reappears. They are reported more frequently in the pictures with long pauses and in the pictures of parallel arrangements with shorter pauses. It is to be remembered that the percentages of the continuous motion are smaller in these pictures and the phenomena seem to be incompatible with it as is the impression of jerkiness.

The great uncertainty, coupled with great individual differences, makes the gray patch in the movement field a ghostly thing, whose nature it is difficult to grasp. On the whole, the size of the gray patch in different series seems to agree with the amount of movement that the bar covered in the movement field. When the pause becomes longer the movement becomes partial and finally stops. It is so with the gray patch. Very frequently remarks are made that the space is not gray but the bar is crossing over it back and forth and makes the space look as if blurred, but it is not blurred really. The bar is blurred because of the quick motion. We incline to take this as a cue to believe that this gray patch may accompany or follow the perception and it is not the necessary condition for the presence of movement. The movement can be perceived without the gray patch being noticed, although it may be present always to a greater or less degree, being itself of central origin.

The recent work of Steinig (46) about "Zwischenstadien" with geometrical figures and animate pictures confirms our belief and tells us more. He says that the "Zwischenstadien" are very indefinite in the single line and not observed by his subjects always

but they are positively sure and clear when complex figures or animate pictures are used. Many other workers (17, 37) find that the knowledge about the characteristics of the object influences the movement to a great extent. These findings suggest the development of movement phenomena: the perception of the object comes first and then immediately there follows the subjective filling up of the physical gap of the stimulus and this completes the perception if all the other circumstances are to some degree in accord with it. It is not at all unusual to find the "Zwischenstadien" very uncertain and obscure in the simple picture like a bar or a dot because it is natural. We never have clear perception of the object during the quick real movement, which fact was confirmed by the works of Dimmick and Scahill (9) and DeSilva (5).

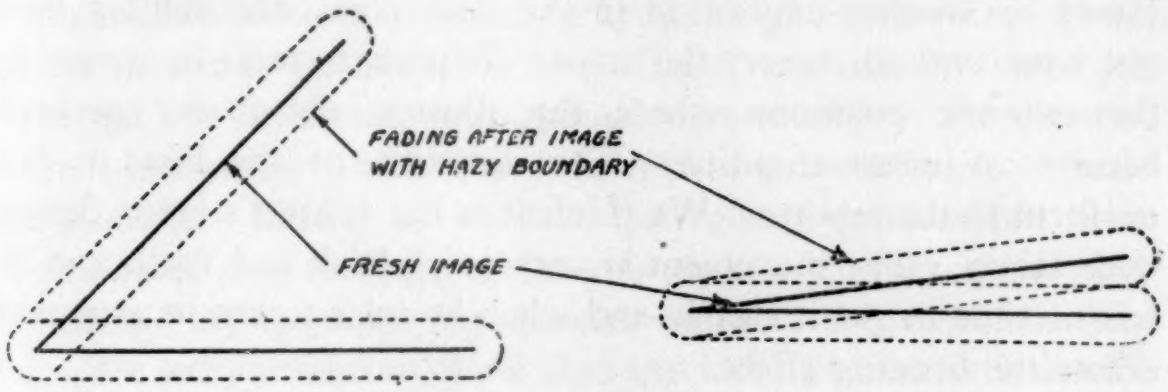
Before we attempt any explanation of these visual phenomena we need to state our fundamental assumptions upon which we rest our discussion. Every one will agree in assuming that all psychic activity whether aroused peripherally or centrally has a corresponding psycho-physical process in the higher centers, which may be aroused almost simultaneously with or a little later than the application of the stimulus and may keep its strength for some moments after the physical stimulus is extinguished and then wanes gradually. Intensity and duration of this psycho-physical process are proportional to the intensity and duration of the stimulus, provided no other influential factors work simultaneously. When there is another stimulus working partly simultaneously or successively to the first one the psycho-physical process corresponding to the second stimulus influences that of the first and *vice versa* as Waals and Roelofs say, by lengthening the "Wahrnehmungszeit" for the second stimulus because of the presence of the first, or by cutting short the "Wahrnehmungsdauer" of the first in order to perceive the second as soon as the second stimulus is applied. This all depends upon the behavior of attention and fixation. In our long repeated expositions this variation in the psycho-physical processes modified by the mutual influences can not be detected at each exposition and differentiated from one another, but we have to take it in the sum total. It is

certain that any slight influence shows a summation effect because of the repetitions, and it is clear also that before the psycho-physical process corresponding to the perception of the previous bar disappears, the new psycho-physical process is aroused by the stimulus following in the same place, and this is repeated in each series of pictures with short pauses. The degree of overlapping of these psycho-physical processes is various and depends upon how short the pause is. When the pause is long the psycho-physical process will entirely fade out each time and no overlapping results. When each psycho-physical process dies out or loses its intensity it gives a sensation resembling a flash of light, and when the fading and renewing of the psycho-physical processes follow closely, it gives the impression of a flicker. We are inclined to think that here lies the source of "movingness" sensation. That is, the "movingness" sensation is nothing but a flashing sensation subjectively felt and a mere waning-off process psycho-physically. It resembles very much a spark of light radiating its glow around its source and seems to catch or flow toward the similar spark approaching closely in time and space, but really this does not happen. It is stationary by itself. Only when a meaning is obtained which is the combined product of attention and association do we see motion. This spark is mixed with the rest and we do not distinguish it away from the entire thing.

When we accept the hypothesis that each psychic activity has its psycho-physical process as a basis we can assume that there is a psycho-physical process corresponding to the perception of the physical object and another psycho-physical process follows immediately, corresponding to the centrally aroused perception of the interspace. Then it is evident that when the whole stimulus pattern is so confusing and absurd in itself, no clear perception is obtained and there can not be a clear filling in either, all of which depends upon the first perception, the meaning of the whole thing, but the flashing sensations alone stand out clearly in consciousness. The Gamma movement which Kenkel (32) used for the first time to indicate one of the movement phenomena, namely, contraction and expansion of the bar as it disappears and reap-

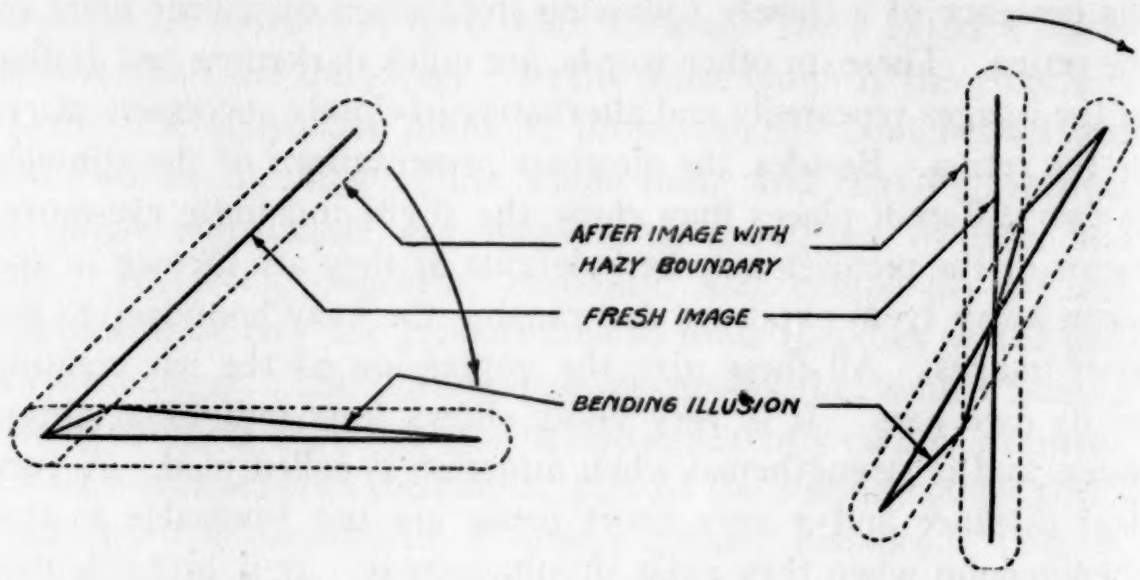
pears, is very likely nothing else but the flashing sensations in its elements. This view is agreed upon by Harrower (23), who came to the conclusion that the main determinants of the Gamma movement were in relation of the figure to the ground and not those of changes of brightness in the ground as Engel said. When the object is as simple as a bar moving back and forth between the two places 45° apart, the subjective filling is naturally simple and easily injured by too long or too short pauses and distances, which do not make the perception of a moving bar probable. Under these circumstances the black bar in the two end-positions stands out very clearly in the subject's consciousness and interferes with a continuous movement perception although there exists a flashing sensation just the same. On the other hand, if the picture is animate, the subjective filling is proportionally complicated and certain to the meaning of the whole thing and lasts longer than the simple one despite the unfavorable conditions of time and space. In short, clearness, certainty, and complexity of the "Zwischenstadien" are proportional to those qualities of the perceived meaning. The phenomenon resembles that which Steinig discovered in his experiment with two differently complex figures, each of which selected the similar part of the second complex in a wandering-over movement, despite a greater distance. That is, he presented a couple of geometrical figures of different shape or type, side by side on a card, through a tachistoscope as the first stimulus and then after a pause of 120 σ he presented another card with similar figures on it, whose positions were exchanged. The one which was on the right side in the first card was now put on the left side and *vice versa* for the left figure. The general shape or type of the figures was the same in both cards but the design of each figure was slightly changed so that the first and second figures of the same shape would make a perspective view of the object and consequently arouse the movement illusion from the first position to the second position of an object. The same phenomenon appeared with two differently dark gray papers which, he says, confirmed Köhler's result on chickens. Many other results of similar types can be explained by the same principle.

When we repeat the same stimulus on the same spots as many times as we did, we must expect the noticeable effect of the positive after-images which distinctly belong to the peripheral process, though it is impossible to separate them from the central process in consciousness. For some of the phenomena the retinal impressions show a causal relation a little more clearly than for others. In the self-rotation of the bar we found that the short pauses and small steps were necessary besides repetitions. The former suggests the necessity of the condition that the fresh impression of the object occurs in the same place as the earlier one, before the after-image of the previous one is entirely gone. The latter means the presence of a closely following impression on a near point on the retina. These, in other words, are quick darkening and fading of the images repeatedly and alternately in closely successive places on the retina. Besides, the alternate presentations of the stimulus in two different places may cause the slight indefinite eye-movements or the pictures may be indefinite as they are thrown in and taken away from exposure and causing the hazy boundary to the after-images. All these give the impression of the bar rotating on its own axis. It is very vivid, shows least individual differences, and is strengthened when attention is called to it. A very near distance and a very short pause are not favorable to this phenomenon when they exist simultaneously. It is probable that the after-image is still very strong and its hazy effect touches that of the neighboring image, and both make the space continuous. Schematic drawings will help to understand this.



The bending appearance of the bar is similarly produced, namely, by impressions following closely on one another and side

by side. There are great differences in the conditions other than temporal and spatial between this and the self-rotation. Individual difference is very great; attention to the fact greatly interferes with seeing it; many repetitions are specially important; the movement must have a definite direction. These conditions indicate that the bending effect is a much weaker or more delicate illusion and the cause of it must be a minor part of the whole perception, which works only during the lack of attention and in non-foveal regions. We are led to think that the hazy effects of neighboring images overlap completely at the pivot and gradually overlap less toward the free ends as the diagrams show.



This overlapping part gives a greater intensity and affects the impression of the whole bar during moments when attention is slight. As the bar is exposed so short a time and is quickly followed by another exposition in the next place, the subject does not have time to correct the error. It persists until he comes to the extreme positions where the illusion disappears perhaps because of more attention. The direction of the bend is not uniform in the reports. We think it is the subject's error due to uncertainty. The movement is very quick back and forth and he has no time to get it clearly and when he tries to see it, attention erases the bending effect.

The origin of the gray patch is now clearer. It may be due both to subjective filling and retinal radiation or hazy boundary of the after-image caused by the slight movements. Since the

stimulus objects are simple they are not distinguishable in consciousness and the cause of its irregularity is attention and differs in the individuals. When the space is attended to the subject becomes critical and the dark images of the bar stand out very clearly and push out all other things from consciousness. It is customary not to take the retinal radiation into conscious consideration, and the subjective filling is almost unnecessary in such a simple object in quick movement. For some individuals the knowledge of the mechanism of the kinematographic motion forces them to deny any filling of the gap, although in the animate pictures and complex figures this subjective filling is almost compulsory, according to Steinig.

All the remarks that our subjects made in Experiment I about the appearances of the movement field and the bar are clear now as to their causes, namely, subjective filling, radiation effect of the retinal images, attention, and individual peculiarities.

If we believe the discoveries of Dimmick and Scahill and DeSilva that the moving bar is not at all clearly perceived during the quick movement even in the real movement, it does not seem sound to agree with Waals and Roelofs when they insist that the bar must be seen clearly moved from one place to another without a suspicion of a break to constitute the optimal apparent movement. Since they used very long exposure times their results must have different characteristics and it seems not fair to compare their results with others who used much shorter exposure times.

Waals and Roelofs say that most investigators used too great spatial distances between the two stimuli and their results are suspected not to be the true optimal movement but the pseudo-optimal movement which is a different thing according to Waals and Roelofs. If it is so we have no right to speak about their results from our findings. However, we wish very much that they would try the same experiments on more subjects than they did. We are inclined to think that the individual variations will bring out some evidences in favor of our view. Our subjects, excepting a few, insisted that the bar was seen only in the two end-positions but the movement was surely there. Waals and

Roelofs may say that it is an " inferred movement " and not a " seen movement ". In our opinion the inferred and seen movements are not different in nature but rather matters of degree and differences in the individuals. There is always something like inference working in any complex mental activity, which is markedly noticed by the subject in the simple picture but not so much in animate and complex objects because the meaning and complexity of the pictures occupy the whole consciousness and leave no room for the mind to notice their being centrally supplied through the association process. Steinig used 50 σ or exposure time and 120 σ for pause and obtained a vivid filling of the interspace. This is nothing but a result of what Helmholtz called unconscious inference. The beginning phase of the jumping boy is shown; the subject perceives it as a boy in a certain posture but very likely no movement is yet suggested. Following a blank period another picture is shown which tells the final [illegible]e of the jumping boy and it is perceived. These two perceptions of the beginning and end pictures suggest the whole story, the " Zwischenstadien " being supplied subjectively after the terminal picture is given and lasting as long as the " Wahrnehmungsdauer " of the terminal picture lasts. The subjective filling is, therefore, a mere conscious experience, being itself another perception centrally aroused by the two perceptions. This inverted order in the event can not be noticed by the subject because it is absurd to the perception of the whole story as long as the temporal condition remains within certain limits. Without unconscious inference this phenomenon can not be thought of as existing. As we mentioned before in the case of a bar, the conscious experience of the movement is just the same whether or not we see the clear " Zwischenstadien ", which are not necessary in the quick movement, real or apparent. Korte's Delta movement (35) is not impossible according to our principle, and it is not a peculiar phenomenon as Waals and Roelofs say it is. We can see a possibility of movement occurring in the inverted direction under a certain condition of attention and fixation point in the visual field.

The Wheel Rotation:

There has been much discussion recently of why at times in moving pictures the wheels of cars sometimes reverse the direction of rotation and sometimes merely move spasmodically. Gradle (18), Guilford (21), and Ferree (15) have reported and discussed such phenomena. We reproduced the phenomena by taking a moving picture of a rotating card board disk that had radiating black lines drawn upon it to represent spokes. We found that different parts of the film showed different effects. At certain points the pictures seemed to rotate clockwise as did the real disks, at other parts of the film, the rotation was counter-clockwise and at still other parts the disk would seem to hesitate in its motion, moving a little clockwise, then a few inches back, and so merely to oscillate without real rotation.

When the successive pictures were studied closely, it was found that when the motion was seen as clockwise each successive picture showed a spoke a little to the right of the preceding, but less than half way to the next radius. When the motion was counter-clockwise, each succeeding impression was a little to the left of the preceding, or between the half way point and the next radius. This point would be attained by going more than half the distance to the next radial line or some multiple of the distance between the radii plus the half way distance. If the successive exposures caught the radii at points nearly half way between the adjoining radii, there would be the motion back and forth between the original position and the position half way between the adjoining radii. When it appeared that the disk was not going anywhere but seemed wavering in the same position, the successive exposures caught the radii at points nearly superimposed upon the position of the preceding one, or a little to the right and then a little to the left of the preceding one. There were moments of a standstill appearance of the disk. This phenomenon would be attained when the radii in the succeeding exposures exactly coincided with those in the preceding. Such an occurrence was very seldom and was limited to the disk which had six radii and none appeared in those that had one and four radii. All six radii very seldom coincided with the preceding exposure.

We then performed an experiment in which we produced these same phenomena artificially. We prepared a series of simple radiating lines, in which the successive exposures could be displaced at will. It was found that when successive exposures were less than half of the distance which separated the spokes to the right of the preceding exposures, the rotation was clockwise. If the successive positions were to the right more than half the distance between the spokes, the motion seemed to be counter-clockwise. In this case the given spoke was associated with the succeeding one which was nearer in space and it was assumed that it had moved back rather than forward. When the positions of the spokes in the succeeding exposures fell approximately on the point half way between the original adjacent spokes, it depended upon the attitude of the subject whether there was a clockwise or counter-clockwise rotation, and when the same condition repeated itself the motion would be felt back and forth between the original position and the central position on its right or the central position on its left. It seemed to be possible to find the exact displacement in degrees of the succeeding spokes that produced this back and forth movement. In spite of the individual differences and the subjective conditions which might cause variations in the degrees of displacement, it was evident that there was a range where the motion was present but undetermined in direction, and the size of the range varied greatly with different numbers of spokes. The more spokes there were, the smaller was the range of the undetermined direction, and a slight variation was the more noticeable. Consequently a slight difference in the displacement of the spokes was sufficient to change the direction from clockwise to counter-clockwise.

Numerous spokes of the wheel and a great speed of the propeller are the best conditions for the production of these varieties in the phenomenon although these are the real movements and ours are apparent movements. According to the findings of Dimmick and Scahill and DeSilva comparing the real movement with the apparent movement we feel justified in applying our results to Gradle's and Guilford's observations. Thus we suggest a possibility of objective causes for the unexplained visual

phenomenon of the propeller and the spasmodic wheels of the moving car in addition to Ferree's and Guilford's subjective causes.

Comparison of Apparent Speed:

As we have seen in the other experiments the apparent movement changes its appearance greatly along with a change made in any one of the factors concerned in its appearance. Therefore it is clear that many things are influencing our speed comparison when we use such variables as pause and distance between successive stimuli. In the most simple picture where we varied only the distance, keeping the pause constant at 70 σ, as in Experiments XV and XVI, we found that the rotary motion of a radius showed more normal results than the back and forth motion of a bar in the angle form. That is, in the rotary motion of a radius the right judgment in the speed comparison increased as the difference in the speed of the two compared movements became greater, as well as when the ratio of the same became larger; while in the back and forth motion of a bar no such proportional increase was seen, having about 50 per cent wrong judgments in all the series of pictures. The back and forth type of motion must be responsible here in preventing the distance from playing its part. However, there was some evidence that the influence of the greater distance was not entirely nullified, for as a whole, slightly more " faster " judgments were given to the movement which went the greater distance at each exposure of the bar. The total number of wrong judgments was greater in the pictures showing back and forth motion. The speed of the second member in the pair was judged as faster than the first very frequently in both types of motion, but more so in the back and forth motion.

The next most simple pictures were those in which the length of pause was varied and the distance, 45°, was kept constant. Since the variation of lengths of pause was made in a wide range we must expect that the appearance of the movement would vary from the optimal stage to almost stationary succession for some subjects at least. Here we found different results. The rotary motion of a radius showed a better correspondence between the number of the right judgments and the ratio of the two speeds,

but not so good a one between the number of the right judgments and the difference of the two speeds; while the back and forth motion of a bar in the angle form showed a close correspondence between the number of the right judgments and the difference of the two speeds. We must now point out what significant difference there is in the ratio and the difference of the two speeds compared.

When we say a ratio of two speeds we take both the exposition time and the pause into consideration, for we add them and divide the sum by a similar sum in the other member of the pair in order to obtain the ratio. On the other hand, a difference of two speeds is obtained by subtracting the whole time (exposure time plus pause) taken for the bar to go a certain distance by one of the members of the pair from the whole time taken by the other member. This is the same thing as the difference in the lengths of pauses alone, as we used the same exposure time all through. This explains the different results in the two types of motion. That is, the pause shows its influence more conspicuously in the back and forth motion and less in the rotary motion, and the subject uses different appearances as a cue for his judgment. The fact that the total number of wrong judgments was far greater in the rotary motion strengthens the probability of this explanation. This cue seems, however, to be impaired when the gap is too long because in both types of motion the slower movements in both members of the pair were misjudged more frequently than faster movements.

The distance covered within a certain period of time was the same but the bar was shown a different number of times within that same distance and time in both members of the pair. This arrangement seemed to have caused a confusion in the subject's mind, for the number of wrong judgments was greater in this than in any other experiment. In the rotary motion great distances with long pauses and short distances with short pauses were judged as faster. In the back and forth motion the great distances with long pauses were perceived as faster more frequently than the small distances with short pauses. The judgment "same" was most frequent in the pictures $II^2 : III^1$ and

$II^5 : III^3$. (The Roman figures indicate the number of steps taken by the moving bar within the 45° distance, and the Arabic figures indicate the length of pause in terms of the number of blank sections of the film. See Tables XIV and XV.)

In the last experiment of the speed comparison the pauses and distances between successive exposures were varied so that the entire distance also varied. In both types of motion the ratio of the two speeds showed a better correspondence with the number of the right judgments. The more the appearances differed between members of the pair, the more the right judgment was given. Slow motions were harder to judge correctly. The speed of the second member was judged as faster in many more cases than corresponded to objective conditions. The wrong judgment was more in the rotary motion than in the back and forth motion.

From these various results the following things are deduced. The speed of the second member tends to be accelerated, the cause of which is very likely physiological. The time element has very much to do with the speed perception. When we made the interval constant for equal distances in both members a greater confusion occurred and the subject seemed lost trying to find a cue in this or in that, especially in the rotary motion in which both the greatest distance and the smallest distance were taken as the cues for the faster movement. In spite of the instruction the subject might have been trying to see a difference more than an equality of the speed in the two members. The fact that there were more misjudgments of the speed when both movements were slow indicates that the consciousness of strain or rhythm which measures time has a limit and can not work efficiently beyond that limit in spite of other differences which otherwise serve as cues. The spatial distance between succeeding stimuli serves as a cue in both types of motion, the movement with the greater distance being interpreted as faster. It may be due to the slighter feeling of strain over the large empty space while in the movement with exposures at short distances the same period of time is filled with additional exposures, which interferes with the pure consciousness of time.

The appearance of the motion which is produced by different lengths of pause serves as a good reference for the judgment of speed but the noteworthy thing here is that the effect of pauses is not the same in the two types of motion. It shows itself more conspicuously in the back and forth motion than in the rotary. It is because perhaps in the back and forth motion the alternate direction at each exposure causes over-lapping of the after-image and the primary image, which fact makes the gap more conspicuous. For those subjects who see the gray patch or the blurred bar in the motion field the back and forth repetitions will double or treble the degree of grayness or blurness, while all these things are absent in the rotary motion.

The spatial distance alone is a good cue in the motion in one direction alone but not in the back and forth motion. It is simply because in the former all distances are added into the entire distance of the motion while in the latter each distance is shown by itself and not summed up.

In conclusion we can say of the judgments of speed that we have a stronger tendency to judge the speed of a motion in terms of time than in terms of distance. The appearance of the motion field influences the judgment of time. If the field is empty the time is considered to be short and the motion made over it fast, and if it is filled with additional expositions the motion is judged as slow although the time elapsed is the same. When the appearance of the motion field is very similar in both members the time consciousness functions by itself and when time is made equal in both members the subject uses anything as a cue adopting consciously or unconsciously the most favorable method for forming his evaluations of comparative speeds.

All through the various experiments we can see that what we are trying to do is to set up as concrete a relationship as possible from all impressions, and to supply the lacking parts as much as is reasonable, and keep them functioning as long as possible. You may call this behavior of mind self-dynamic or Gestalt or else a chain of reflexes. It is evident that the physical stimulus is working upon the sense organ and sets up sensory, neural and physiological changes, which may be transmitted into,

or accompanied by, mental processes leading to sensation, perception, or comparison. Any discrepancies between the physical stimulus and the perception must have taken place within us. We know some facts about the physiological processes in the retina that are set up by the stimulus and the final product, but from beyond the surface layer of the retina up to the point of judgment we are still in darkness. Only speculations give us imaginary pictures of these dark regions. Our imagination tells us that the path is a long complicated one where there are innumerable junctions and cross-ways and some of them are smoother than the others by virtue of repetitions, so that the resultant nervous activities in the higher centers of the brain are different from those started in the retina. All this means that the past experiences and the present sensations are meeting and establishing a concrete relationship into one whole after some kind of differentiation has passed. These two groups of processes are roughly equivalent to mind and body, in short. Since we believe the view that mind and body are the phases of one and same thing, whose functions are inseparably interwoven, any change or disturbance in the one, either from external or internal causes, will necessarily affect the other. This mutual influence is the very characteristic of the organism and lasts throughout life. We use the term psycho-physical process to represent all the processes in these dark regions including the retina, and conclude that the visual apparent movement is a perception not differing from any other perception in the mechanism and the "movingness" is a mere flashing sensation in nature and is interpreted as a motion of some kind by virtue of the circumstances connected with it.

Summary

This is a study of the conditions under which the illusion of movement may be induced by successive exposure of stationary lines in different positions. As stimuli we used lines drawn or photographed on films and exposed by the cine-kodak.

We investigated especially the conditions under which the lines seemed to move back and forth; the conditions which make a radial line seem to rotate in one direction or another, and the factors which make speed of an illusory movement seem to vary.

Where one deals with the simple back and forth movement of a line between two positions, there may be distinguished three types of movement which we designate the Type I movement, the Type II movement and the Type III movement. In Type I movement the line or bar seems to move continuously from one position to the other. The subject may or may not see the bar continuously during the entire time of movement. In Type II movement there is a distinct impression of movement, but the bar distinctly seems to disappear in the interspace. In Type III movement the bar merely flashes on and off at each position of exposure.

The more important results are briefly as follows:

1. The length of the pause between exposures influences the type of motion reported, although on occasion any type of movement may be seen with any pause. The true continuous movement is dominant when the pauses are 70 σ and 130 σ. Mere succession without apparent movement is universal when the pause is 310 σ and dominant if the pause is 250 σ.

2. The patterns of stimuli arrange themselves in the order in which they favor continuous movement with the 45° angle open to the right first, then the 90° angle open below and to the right, the parallel vertical lines and the parallel horizontal lines.

3. When the angle made by two lines is greater than 90°, the nature of the movement changes decidedly even with the optimal pause. The movement is not confined to the two

dimensional plane, but the line seems to describe a cone in the three dimensions. When, however, one or more additional lines are exposed successively between the two end-positions, the bar moves on the plane surface over angles as great as 160° in more than 50 per cent of the cases.

4. Movement loses its definite direction when the stimulus pattern increases its novelty even in the optimal temporal condition, and also when the pause is made very short (10 σ) though the stimulus pattern remains as before. "Movingness" alone is felt in the above cases.

5. Movement is felt very strongly at the pause of 10 σ in spite of the simultaneity of two bars in the angle arrangement.

6. Rotation of the bar on its own axis is seen markedly in the pictures where pauses are short and distances are small between successive exposures. Attention to the fact helps the phenomenon.

7. During the repeated exposures of the bar there is observed an illusion in which the bar seems to bend as it moves back and forth continuously. This phenomenon is favored by short pauses and small distances also, but attention to the fact hinders the illusion.

8. The gray patch, the phenomenal filling of the movement field and the psychological correlate of Phi according to Dimmick, is found to be very uncertain and is not observed by all subjects nor is it always observed by the same subject. On the whole the size of the gray patch seems to agree with the amount of movement that the bar covers in the movement field. When the pause becomes longer the movement becomes partial and finally stops. So with the gray patch.

Rotary Movement:

In the movement of a wheel of the running car we, at times, noticed backward rotation of the wheel though the car was moving forward continuously. The similar phenomenon was reported in the movement of the propeller of an aeroplane. We tried to produce the backward rotation artificially on the screen, using one, two, and three diameters for spokes of the wheel. We discovered the following facts:

9. There exist indifferent areas, which are situated about the middle of the spaces between neighboring spokes. When the spokes fall on these areas in the succeeding exposures the movement of the wheel is observed as fluctuating. When they fall on the space between the original positions and these areas the rotation is clockwise, and when they fall beyond these areas it is seen as counter-clockwise rotation.

10. The indifferent area becomes disproportionately small as the number of the spokes increases, and thereby the definite direction of rotation of the wheel is seen better.

Comparison of Apparent Speed:

Suggested by the spontaneous remarks of the subjects we assumed that there might be an attribute in the apparent movement which corresponds to the speed in the real movement, and we tried to compare two differently constructed apparent movements. They might have pauses of different lengths, or different distances to cover in the equal length of time, or else a different number of exposures within the same distance. The following were some of the facts that we discovered.

11. The speed of the second member in the pairs compared tends to be accelerated.

12. Slow motions are harder to judge correctly than fast motions.

13. There is a strong tendency to judge the speed in terms of time rather than in terms of distance.

14. The appearance of the motion field influences the judgment of time. If the field is empty, time is considered as short and the motion made by the object over it is fast, and *vice versa* for the filled field.

15. When the appearance of the field of movement is very similar and time is made equal in both members, the subject uses anything as a cue depending on the subjective conditions of the moment. That is, the slight difference in the appearance caused by the slightly longer pause may be taken as a larger distance and consequently judged as faster at one time, and at another time he may say that it is slower because his attention has been on the time factor.

STIMULUS PATTERNS *

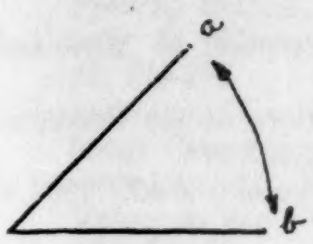


FIG. 1

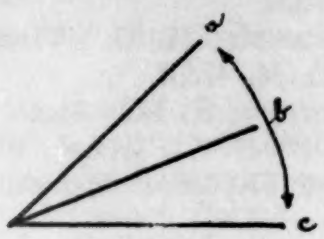


FIG. 2

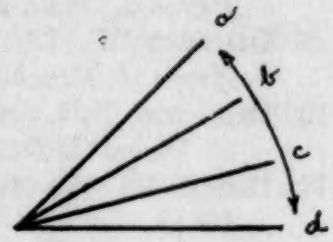


FIG. 3

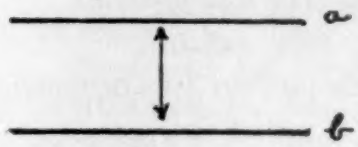


FIG. 4

FIG. 5

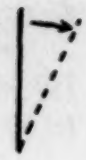


FIG. 6

FIG. 7

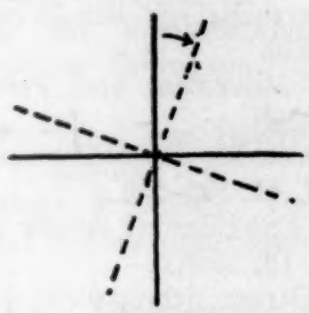


FIG. 8

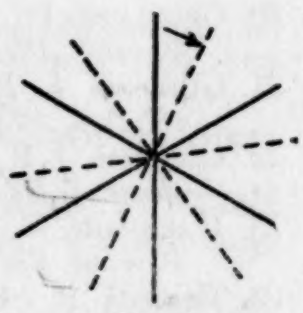


FIG. 9

* The a, b, c, d in Figs. 1, 2, 3, 4, 5 indicate the positions of the bar in the succeeding exposures. The arrow shows the order of the repeated exposures. In Figs. 6, 7, 8, 9 the solid lines show the first position and the dotted lines the second position.

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